THE

POPULAR SCIENCE MONTHLY.

APRIL, 1875.

THE TRIANGLE SPIDER.

By Prof. BURT G. WILDER,

OF THE CORNELL UNIVERSITY.

STROLLING through the woods near Ithaca, New York, one October afternoon, I saw, upon a leafless hemlock-branch, what looked like a piece of the net of some geometrical spider. Still, there was a regularity in this triangular net which did not accord with the idea of its being a fragment. A closer examination showed that its form and structure were perfect and unbroken; and moreover that, instead of hanging loosely from the twigs, it was *upon the stretch*, as if constantly drawn by a power at one or the other end (Fig. 1).

On touching the net to determine its degree of tension, what was my amazement to see it suddenly loosened with a snap, as if let go at one end! Nor was my wonder diminished when, a moment afterward, the the net slowly regained its original condition, by a steady pulling upon a short line connected with the apex. And now I saw the puller—a little dull-colored spider, about one-eighth of an inch long—hanging from the under side of the apex-line, and hauling it in, not "hand over hand," as at first appeared, and as one would suppose by analogy with sailors' operations, but "foot over foot;" in short, with its *hinder legs* moved alternately so as to gradually take in that part of the line which intervened between its body and the twig to which it was attached.

When this line was all taken in, the spider was close against the twig, and its legs were drawn together, so that the whole formed a compact brown mass about the size and shape of a raisin-seed, and differing so little in appearance from the projections of the dried hemlock-twigs among which the net was built, that I felt in part excused for not having noticed the little creature before.

So much for an introduction to a spider which was then new to me, and probably is still unknown to most of my readers. In some respects its habits are unlike those of all our other spiders; and I will here relate what I have learned during five seasons, in the hope that

others may have the fortune to clear up the points in its economy as yet undiscovered.

Our spider is thought by high authorities to be a species of the genus called *Hyptiotes* by Walcknaer, and afterward and more commonly *Mithras;* but the former name has priority. Of this genus two European species have been described; one of which, *H. paradoxus*, has lately been found in England, and described by the veteran arachnologist, Mr. Blackwall. Our American species seems to be that referred to by Hentz as the *Cyllopodia cavata*,[1] but his description is so brief,

FIG. 1.—NET OF THE "TRIANGLE SPIDER," about one-half the usual length. The spider, however, is shown of the natural size.

B B, the base-line attached, at *C* and *D*, to a hemlock-branch; *E F G*, points of attachment to the base-line of the three radii, *R'* to *R''''*, which converge at *A*, the apex of the net; *I'* to I^{IX}, nine transverse or interradial double lines; *S'* to *S''''*, attachments of the first interradial upon the radii; *A L*, apex-line; *O*, origin of the apex-line from a second branch; *Sl*, loop of the apex-line or "slack," between the front and hinder feet of the spider: this is better shown in the lower enlarged figure.

and in some respects erroneous (giving only six eyes, whereas there are eight), that we shall probably avoid confusion by calling this a new species (*H. Americanus*).

Having now identified the spider sufficiently for our present purpose, we have to inquire:

1. Which is *the spider*, the male or the female?
2. How is the net made?
3. How is the net used in taking prey?
4. What are the relations between this and other spiders?

1. WHICH IS THE SPIDER? As is often, although by no means

[1] *Boston Journal of Natural History*, 1847, vol. v., p. 466, plate XXX., Fig. 3.

universally, the case among spiders, the female is the head of the family. In fact, so scarce are the males that for three years I never found one among more than a hundred specimens. This, however, is not absolute proof of their much smaller number, for they are less in size and darker in color, and, like the males of the "silk-spider of

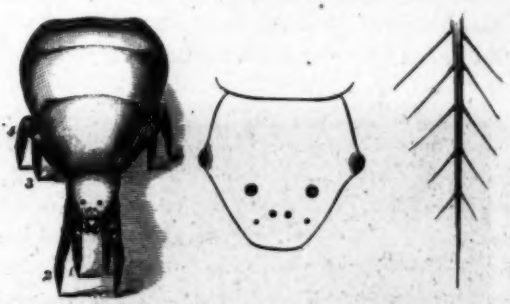


FIG. 2.—At the left a female *Hyptiotes*, enlarged about eight diameters. The legs are marked 1, 2, 3, 4, in order from before backward. In the central figure is shown the front part of the spider (the cephalo-thorax), still more enlarged, so as to display the eight eyes arranged so as to form two crescents with their convexities opposed thus ⌒⌒. At the right is a greatly-magnified feathered bristle from the upper surface of the cephalo-thorax.

South Carolina" (*Nephila plumipes*), they make no nets, but seem to get a precarious living by hanging on to that of some female. Their masculine nature is seen in the structure of the "palp" or feeler, which, instead of tapering to a blunt point, as in the female, is greatly enlarged, its last segment presenting the remarkably complex structure seen in Fig. 3.[1]

FIG. 3.—Terminal joints of the palp or feeler of the male *Hyptiotes Americanus*, much enlarged. (Drawn from Nature, by Prof. W. S. Barnard.)

[1] These modified palpi are undoubtedly connected with the reproductive function. Others besides myself have seen them (with other and larger species) applied to the vulva of the female during an evident copulation; but all do not assent to the generally-received opinion, that they are merely intromittent organs, which have first received the spermatic fluid from the testicular orifice upon the ventral surface of the abdomen. (For a note upon the subject, by Mr. Gedge, with references, *see Journal of Anatomy and Physiology*, 1867, vol. i., p. 371.)

It is possible that, as with the *Nephila plumipes*, the *young* males of *Hyptiotes* construct nets, but of this I can say nothing; for as yet I have never seen what I was certain were the eggs or the very young. Near Ithaca I have found the partly-grown spiders, during the latter part of July, and the adults are all gone before the close of November. Certain little cocoons (Fig. 4), which are quite abundant in the same localities and upon the hemlock-twigs, may prove to be made by this spider, but at present all is conjecture.

FIG. 4.—SUPPOSED COCOON (EGG-CASE) OF TRIANGLE SPIDER.
A, the cocoon, of natural size, hung by thread-lines between hemlock-twigs; *B*, the cocoon enlarged, seen obliquely, so as to show the triangular base.

The form of these cocoons is quite peculiar: it is that of a little sphere flattened upon one side; at three points the border of this flat side is extended into strong lines, by which the cocoon is suspended between the twigs. Its diameter is about one-tenth of an inch, but the lines are often two or three inches long. The ground-color is usually white; but there are always a few black specks, and sometimes these cover so large a portion of the surface as to make the cocoon appear gray or nearly black.

Besides these more common cocoons, the hemlock-twigs sometimes bear others of about the same size, but pear-shaped, and hanging by the smaller end upon a single short line. To identify these, the spiders should be taken in September, and kept in captivity upon hemlock-branches, so that they may make their cocoons.

2. How is the Net made?—Like most geometrical spiders (*Epeiridæ*), the *Hyptiotes* prefers to construct her net just before day. She is then less liable to interruption, and the newly-made net is best adapted for use in taking the builder's breakfast. To these early habits on the part of the spider is owing the fact that, although I have kept many of them in the house, I have never yet been so fortunate as to witness the entire process of net-making. Twice I sat up all night, but the spiders must have begun just as I fell asleep shortly before day; and my readers will understand that, in the midst of the fall term, a professor does not often feel able to spend a night in watching spiders.

However, I have twice witnessed the completion of nets, and have seen enough of the process to enable me, aided by what is known of spiders' methods in general, to infer how the net is begun and carried on, and the correctness of the following description may be accepted as at least probable, until disproved by actual observation of the entire process:

Fig. 5.—*a*, last two segments of the hinder (fourth) leg of a female *Hyptiotes*; *b*, tip of the last segment, showing the claws open; *c*, cross-section of the last segment but one, showing its cavity, in which lie the muscles, and a single curved bristle upon the side, a part of the *calamistrum*; *e*, a similar bristle still more enlarged; *d*, *f*, two feathered bristles from near the joints.

Having first decided upon the general location of her net, the spider probably takes position head downward upon the "leeward" side of a twig or small branch, or upon its top, and then, turning her abdomen outward, expresses from her spinners a drop of gum, which instantly dries so as to form a fine end of a silken thread. This is taken by the wind (and careful experiments have proved that a current of air is absolutely necessary to the extension of the line) and wafted outward, waving from side to side, and usually tending upward from its extreme lightness, until at last it touches some other branch at a greater or less distance from the first. When this stoppage is perceived by the spider, she turns about and pulls in the slack line, until she is sure that the other end is fast. If it yields, she tries

again and again, until successful. If it holds, she attaches her end firmly by pressing her spinners upon the wood, so as to include the line. The first and most important step in the construction of all geometrical nets has now been taken, and the spider can meet with no serious difficulty in completing her task.

But the following steps might be taken in more than one way, and perhaps are so at different times, or by different individuals. And, in view of the risk of making inferences as to the habits of animals, I refrain from the description of what may occur, and simply state that in some way the spider connects with the original horizontal line four others, constituting respectively the base-line (*B B*) of the net, and the three lower radii (*R'' R''' R''''*) which are joined to the base-line at *F*, *G*, and *H*. The upper radius (*R'*) is formed from the central part of the original line, and the three others unite with it at *A*, the apex of the triangular net. (*See* Figs. 1, 8, 9.)

The framework of the net is now ready, and the spider begins to construct the more essential part of its snare.

The organs directly concerned in the operation are the hinder pair of legs and the spinning mammulæ, or spinnerets.

The fourth pair of legs have, upon the last segment but one, a series of strong and curved spines, forming a rake with teeth finely set. When used, this rake appears to be carried backward over the spinnerets, so as to draw out the silken threads.

It seems to represent the *calamistrum* of the other *Ciniflonidæ*, but has no such effect, as with them, as to form a flossy border upon the silken thread.

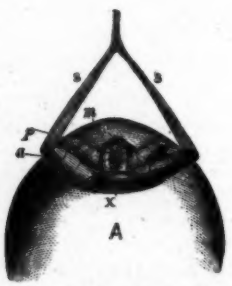


FIG. 6.—VIEW OF THE SPINNING APPARATUS OF *Hyptiotes Americanus*, FROM BELOW AND IN FRONT.

A, the lower surface of the abdomen; *v*, the vent or outlet of the intestine, opening through a papilla; *a*, one of the anterior pair; *p*, one of the posterior pair; *m*, of the middle and smaller pair; *x*, a low oval projection just in front of the spinners, which seems to correspond to the fourth pair in other species; *s s*, the silk from the anterior spinners, uniting to form one line, but capable of drying so as to form the two strands of the double interradial. I do not know from which spinners the various parts of the net are formed.

The *spinning mammulæ*, or *spinnerets*, are represented in Fig. 6. They form a little group upon the lower surface of the abdomen, near its hinder end. In a state of rest, they are closely approximated, but when in use they are more or less widely spread apart like so many fingers or short legs. Indeed, there is reason to regard the spinners as

corresponding in essential structure with the true legs of the spider. They are jointed or articulated, and capable of considerable movement. Their number and form vary with different genera. In our spider there are three pair, anterior (*a*), middle (*m*), and posterior (*p*). The middle pair are smaller, and ordinarily concealed by the others. Behind the spinners is the median papilla through which opens the vent (*v*). In front of them is a low, broad, oval-topped papilla (*x*), in which I find no trace of division into two, nor any silk-tubes. It probably represents the fourth pair of spinners, which exist in the other *Ciniflonidæ*.

The tips of the spinners are provided with many little tubes, having the appearance seen in Fig. 7. Through these is drawn the gum

FIG. 7.—A SINGLE SILK-TUBE FROM THE END OF AN ANTERIOR SPINNER.

secreted by the silk-glands within the abdomen, and all the strands from a single spinner may combine to form a single thread.

It is probable that the different pairs of spinners are supplied from different glands, and that they are employed in making different parts of the net. With the *Nephila plumipes*,[1] I found that from one pair came only white silk, while another pair produced only yellow. By separating these with pins, soon after leaving the body, and attaching

[1] For an account of this species, and of the *Epeira riparia*, see the following papers:

"On the *Nephila plumipes*, or Silk-Spider of South Carolina" ("Proceedings of the American Academy of Arts and Sciences," November, 1865).

"On the *Nephila plumipes*" ("Proceedings of the Boston Society of Natural History," October 4, 1865).

"On the Silk-Spider of South Carolina; Four Lectures before the Lowell Institute, March, 1866" (unpublished).

"How my New Acquaintances spin" (*Atlantic Monthly*, August, 1866).

"Memoirs of a Cripple" (*Our Young Folks*, September, 1866).

"Researches and Experiments upon Silk from Spiders" (Termeyer, 1810–1820?) edited by B. G. W., and published in the "Proceedings of the Essex Institute," Salem, Mass., July 6, 1874.

"Two Hundred Thousand Spiders" (*Harper's Magazine*, March, 1867).

"The Practical View of Spider's Silk" (*The Galaxy*, July, 1869).

"The Habits and Parasites of *Epeira riparia*" ("Proceedings of the American Association for the Advancement of Science," 1873).

'The Nets of *Epeira*, *Nephila*, and *Hyptiotes* (*Mithras*)." (Ibid.)

them to a cylinder, the two colors were wound separately from the living spider. Thus far, however, I have failed to ascertain their distinction with this species. So my figure and description may not be correct in assigning to the anterior pair the duty of supplying the interradial lines.[1] However, it seems probable that the process is as follows: One or more pairs of the spinners are first pressed together and then separated. This draws out the silk as a band connecting their tips. By keeping them apart, and repeatedly carrying the *calamistrum* backward across their tips, the lines from each of the two mammulæ in one pair are kept separate until thoroughly dried. When the line is completed and drawn taut they remain distinct, but very near together.

We are now ready to observe the way in which the spider employs the organs above described. Let us suppose that the framework of the net is completed, and that the first or longest interradial line (Fig. 8, *I'*) has also been made. Instead of beginning the second interradial at *S''''*, she begins at 4; and instead of climbing up the interradial or the strong and convenient base-line (*B B*), she runs to a point (2) near the apex, crosses the two intermediate radii, and passes along the upper radius to the attachment of the first interradial (*S'*). On reaching this, she turns and moves for about her own length toward the apex. Contrary to the usual habit of spiders, during this roundabout passage from 1 to 4 she spins no thread. She now spreads her spinners a little, and presses them upon the radius, keeping them so while she advances again about her own length. This forms the attachment of the second interradial. The spider then lets her abdomen fall somewhat, supporting her body and advancing upon the line by means of her first, second, and third pairs of legs. The fourth pair are applied together to the spinners with great rapidity, at least five times in a second or three hundred times in a minute, and in so doing they draw out a *double line*.[2]

The spider moves slowly along the radius until she reaches a point (5) where she can step across to the next radius (*R''*). While so doing, she ceases to draw out the double line, and carefully keeps it from

[1] From a notice in the *American Naturalist* for February, 1875 (page 125), it appears that Mr. A. J. M. Underhill has lately published, in *Science Gossip*, some observations upon the employment of the different pairs of spinners. He assigns to the third (middle?) pair the production of a line which is either viscid or curled.

[2] I must here admit an error in a previously-published account of the net ("Proceedings of the American Association for the Advancement of Science," 1873, pages 264–274). The interradial lines were there described as *viscid*. The fact is, that I had never thought it necessary to examine them under the microscope, since the interradial lines of all the *Epeiridæ* are viscid; that is, consist of a slender axis enveloped by a viscid coating, which, soon after the net is completed, runs spontaneously into minute globules. Finding that the interradial lines of the "triangle-spider" were elastic, and that they readily adhered to the prey, or to any other body, I not unnaturally, but most unscientifically, drew the inference that with this spider the lines were likewise viscid. During the summer of 1874, while examining the manner of attachment of these lines to the radii, I saw that the interradial lines were neither viscid, like those of the *Epeiridæ*, nor provided

contact with either of the radii. She then retraces her steps along the second radius to a point (6) nearly under that whence she started. The double line has shortened itself considerably; any slack she draws in, and then, turning about, with her head toward the apex, she makes a second attachment with her spinners close pressed against the radius.

FIG. 8.—NET IN PROCESS OF FORMATION.

The framework is completed, and the first interradial line (*P*) has been made. The subsequent movements of the spider are indicated by the figures 1 to 9, and by the interrupted lines and arrows. The *dashed* line 1, 2, 3, 4, shows the route which the spider followed in order to commence the second interradial. The *dotted* line 4, 5, represents her track while pulling out the first section of the interradial line; the dashed line 5, 6, shows her return to the proper point for attaching it. The dotted line 6, 7, and the dashed line 7, 8, in like manner indicate the track over which the spider passed in forming the second section of the second interradial. The dotted line 8, 9, shows the progress of the spider toward making the third section. The net is considerably reduced, but the spider is of about her usual size.

This done, she again hangs from the radius, draws out the viscid line, and advances toward the apex, crosses at 7 to the third radius (*R'''*), retraces her steps thereon to 8, and makes a third attachment. She then repeats the same process upon the third radius, and, in Fig. 8, is represented as having finished about one-half of the line.

It must be borne in mind that the spider is not reduced, like the net; and also that, to save space, the interradial spaces are not so wide

with a fine floss, as with the other *Ciniflonidæ*, but simply *double lines*, the two strands being from $\frac{1}{100}$ to $\frac{1}{1000}$ of an inch apart.

My error exemplifies the utter insufficiency of property and function as a guide to structure, and enforces the general principle in natural history, that nothing should be stated as a *fact* that has not been verified by *observation*. It was his avoidance of this kind of error which rendered the work of the late Prof. Jeffries Wyman so remarkably trustworthy.

Since the foregoing was in type, I have learned from Mr. J. H. Emerton, of Salem, that some of his observations upon the structure and economy of this spider do not accord with those here recorded. It is to be hoped that the views of this accomplished and enthusiastic arachnologist will be incorporated with the new edition of Hentz's papers, which he is preparing for publication by the Boston Society of Natural History.

as in Nature. The remaining interradials are formed in like manner, their number varying from six to fifteen.

It will be seen that, by first making the double line nearest the base-line, and afterward the others in their order, the spider avails herself of the fact that a less and less distance is to be successively gone over before crossing from one radius to the next; whereas, if she made the shortest double line first, then she would either be liable to entangle the other if she crossed at the apex, or, if she went around by the base-line, the distances to be gone over would constantly decrease *inversely* to the lengths of the double lines themselves, causing either waste or entanglement.

It is not yet certain just how long a time is required for making the entire net; but, in one case, the spinning of the five lesser viscid lines occupied the spider ten minutes; the other and longer ones may have taken twice as long; and, as the return-movements are rapidly executed, we may say that, for at least half an hour, the little spider is moving her hinder legs together and with great precision at the rate of 300 times per minute, making the total number of movements 9,000!

How is the Net used?—If the making of the net is peculiar, its use is even more remarkable; and here, fortunately, few points remain to be cleared up; for the spider's response to a disturbance of her net by a fly is so prompt that one may, at any time, witness the operation.

At the close of what to the observer seems a pretty energetic exercise of all her faculties and powers, the spider, without a moment's rest, goes to a point upon the apex-line about an inch from the origin (*O*), and, firmly grasping the line between the first and second pairs of feet, she walks backward, foot over foot, until her hinder feet are caught in the attachment itself, or in the thickened line near it; in so doing, a certain amount of slack-line has been furled up between the two points held by her hinder legs and the front ones; this slack is kept away from her body by means of the third pair, which are shorter than the others. Evidently the effect of the above operation is to draw the net toward the apex, the two middle radii being most affected, and with them the central portion of the base-line to which they are attached; and the whole net assumes the appearance shown in Fig. 1.

It is now upon the stretch; and the degree of tension is very considerable, judging from the violence of the snap when it is let go; the exact amount has not yet been measured, but, when it is borne in mind that the spider remains motionless for hours, perhaps for days, constantly holding her net ready for action, we may conclude that, as is the case with other insects, her powers and her endurance are, in proportion to her size, quite beyond what we are familiar with among the higher animals. But our spider's ability to keep still is fully

equaled by her capacity for action when the moment arrives; and yet she is by no means hasty; as a general thing (the exceptions being due perhaps to hunger, or inexperience), the vibration of the net by an insect must be pretty decided, and at least once repeated, before the spider feels justified in springing her trap; and when, as may sometimes happen naturally, but more often through experiment, a large or fierce insect is put into the net, nothing will induce the spider to budge; she will suffer her net to be wholly destroyed rather than expose herself or her reputation (?) to a doubtful encounter. Let us suppose, however, that a common fly, or a gnat, or a moth, has

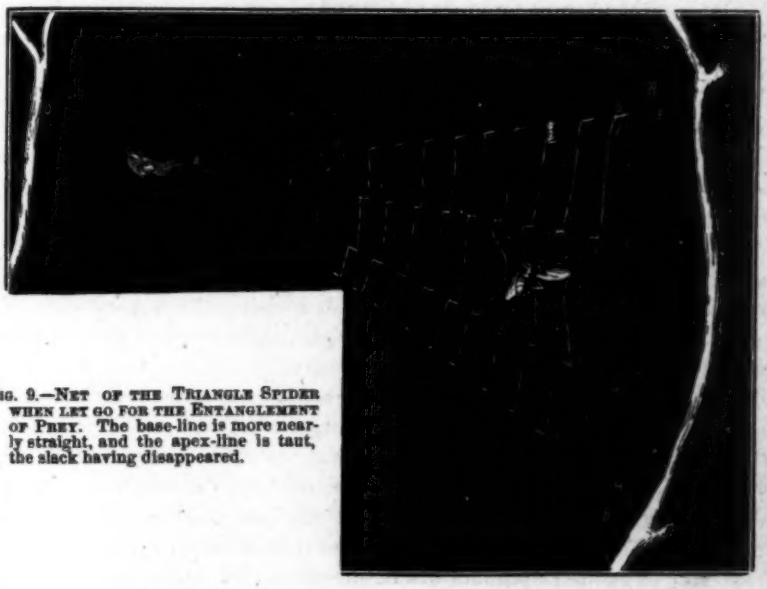


FIG. 9.—NET OF THE TRIANGLE SPIDER WHEN LET GO FOR THE ENTANGLEMENT OF PREY. The base-line is more nearly straight, and the apex-line is taut, the slack having disappeared.

struck the net in passing—it may have touched a single double line—but this adheres with the greatest tenacity, and is so elastic as to yield without breaking, so that each struggle involves the victim still more, and may even bring it into contact with the next interradial. As soon as the violence and repetition of the vibration indicate that an insect is really entangled, the spider awakes from her apparent apathy; she lets go with her hinder feet; the net, released from its tension, flies forward, and at the same time flaps from side to side.

The comparative inertia of the fly causes the two or three double lines next to it on the side toward the apex to be, as it were, propelled against it, and the entanglement is aided by the sidewise flapping already mentioned; as may be imagined, all this is pretty apt to involve the fly beyond the possibility of escape; but, if the spider does not feel certain of this, she creeps backward again, foot over foot, as

before, and again springs her net; and this I have seen repeated in quick succession *six times* before the spider has ventured to make a personal approach. She has already been carried a little way toward her prey by the snapping of the net, for she always retains her hold of the apex-line by her first two pairs of feet, and the third pair serves to steady her as the slack-line slips between them. Advancing now to the junction, she seems to ascertain the exact location of the fly by pulling upon the radii.[1] Having decided, she runs along the chosen radius, and sometimes, when the prey is small, or hopelessly entangled, contents herself with pulling it up by means of the lines about it, and carries it to her accustomed station to be eaten at her leisure.

But more often she adopts a method of securing her prey which, so far as I know, is peculiar to this genus, and involves the destruction of her entire net.

Before reaching the apex (*A*), she cuts with her jaws the apex-line, but, as she keeps constant hold in front of the cut by her first and second pairs of feet, and has a communication in the rear through the line which most spiders always attach to a point behind them, she does not fall, neither is the net loosened beyond a certain limit; it usually seems to recoil about an inch; this recoil tends to entangle the prey like the original snaps of the net. The spider again advances, gathers the radii together and cuts them all, still keeping the line out behind; again the net recoils and collapses. Again she advances and cuts the radii; the net is now hardly distinguishable as such, and is falling together about the devoted fly; the spider now spreads her legs, gathers the net between them and flings it like a blanket over her victim; struggles are now in vain; but, "to make assurance doubly sure," the spider grasps the mass, transfers it to her third pair, and with them turns it over and over as a ball, hanging the while by her front legs, and, with the hinder pair used now *alternately*, drawing out from the expanded spinners broad sheets of silk which, relatively to the power of the fly, are like steel bands upon a man. Having in this way reduced the prey to a rounded ball, in which its limbs are hardly distinguishable, the spider takes it in her jaws and mounts to her place.

A single fly of ordinary size seems to occupy a whole day in the eating. When finished, the remains are cast down as a pellet, so perfectly deprived of moisture, that it is probable that this species, like the *Nephila*, and perhaps all *Epeiridæ*, sucks out the gum of its old net and reëlaborates it in her organs for use in making a new one.

Whether this peculiar economy is practised or not, it is certain that the *Hyptiotes* often sacrifices its whole net in the capture of a single fly; and that the making of this net involves an amount of labor and of skill which one would think not lightly to be thrown away.

[1] As with the *Nephila*, and perhaps all other geometrical spiders, this species seems to perceive *light* only, and not to see objects distinctly.

THE RELATIONS OF HYPTIOTES.—In these days of evolution, we can hardly wait to learn what an animal does in the present, before we inquire what its ancestors were, and how it came to be what it is.

Ideally, one may at once draw a curious comparison between *Hyptiotes* and two other spiders already referred to in this article, namely, the *Epeira* and the *Nephila;* for the net of the former is a complete circle, that of the latter is a circle lacking its upper sextant, while the net of *Hyptiotes* is just about the sextant or sixth of a circle. To use a more homely comparison, the net of *Epeira* is an entire pie, that of *Nephila* is a pie with a piece cut out, while that of *Hyptiotes* represents the missing piece. In algebraic language, *Nephila* + *Hyptiotes* = *Epeira*.

FIG. 10.—DIAGRAM REPRESENTING THE FORMS OF NETS OF NEPHILA (N), HYPTIOTES (H), AND EPEIRA (E).

But, while the above comparison enables us to contrast the nets of the three genera, it by no means satisfies the inquirer as to the derivation of the forms in question. To answer this in full would require a more complete knowledge than we now possess, and would involve a discussion too technical for these pages; but there are a few considerations easily presented, which indicate that the gaps between the forms are not so great as at first appears.

1. The net of the ordinary geometrical spiders, like that of *Epeira riparia*, consists of a continuous spiral viscid line laid upon radii, while that of *Nephila* presents a larger number of radii upon which is laid a *looped* viscid line, which does not extend across that part of the circle just above the centre. But in several nets, otherwise of usual geometrical character, I have found one or the other side, but usually the bottom, extended considerably by the addition of several *looped* lines, like those made by *Nephila;* so that we may imagine that *Nephila* has merely perpetuated and intensified into constancy a method of net-making which was occasionally employed by the form from which it and the common *Epeira* are both descended.

2. At least one species of *Epeira* (the *E. calophylla* of Great Britain, described by Mr. Blackwall) constructs a net of looped lines, like that of *Nephila*, but the loops terminate on both sides of a *single* radius, which serves as a line of communication between the centre of the net and a cell under a neighboring leaf. Now, if we imagine the net to be reduced from many radii to four, then the single divergent radius of *E. calophylla* would represent the apex-line of *Hyptiotes*

3. Many and perhaps all geometrical spiders are accustomed to shake their nets violently when touched, and sometimes to seize

several radii in their claws, and draw them up and let them go suddenly; such a habit may have been the foundation of the remarkable device adopted by *Hyptiotes*.

One further inquiry is suggested by the fact that the net consists invariably of *four radii*. Whatever other variations there may be in the spider's work, as to the size and proportions of the net, and the number of interradial lines, the *number of radii is constant*. In more than a hundred nets, I have found the number to be *four*, never more nor less. Now, this seems to offer a confirmation of the common idea that spiders' webs, like bees' cells, are constructed with absolute accuracy, and are models for poor humanity.

FIG. 11.—NET OF *Nephila plumipes*, made in a wire frame, and photographed upon wood; reduced. In nature, the free radii, as above described, occupy about ½ of the area; but the web of which a figure is given was made upon a frame, the limits of which seem to have interfered with the extension of the loops above the level of the centre of radiation.

But Prof. Jeffries Wyman has shown that *no such exactitude prevails with the cell of the honey-bee;* for, while the average diameter of a large number of worker cells is about one-fifth of an inch, yet the difference between two cells has been found to be one-fortieth of an inch, and the aggregate diameter of ten cells may differ from that of another set of ten cells one-fifth of an inch, or the diameter of a single cell. The width of the sides varies to an appreciable extent; likewise the angles between the sides; a fourth face is often introduced into the base, and the rows of cells may be greatly out of line; in short, while it is probable that the bees work with reference to an ideal or type implanted in them, Prof. Wyman is inclined to *doubt whether a type-cell is ever really made.*[1]

The reader will now be prepared to hear that, after careful examination of large numbers of nets of many different spiders, I have yet to find one in which the irregularities could not be detected by the

[1] "On the Cells of the Honey-bee" ("Proceedings of the American Academy of Arts and Sciences," January 9, 1866, pp. 68–82; 6 figures).

eye. The radii and viscid lines differ in number (the number of radii being constant only in *Hyptiotes*). Their distance apart varies greatly, as might be expected from the fact that spiders make their measurements hastily, and with no apparent attempt at precision; in fact, the irregularities are such as would disgrace any human artificer. We must conclude that the popular belief upon the subject is based upon very superficial observation, and that it had its rise in the old theological idea that because the Creator is perfect, so must be the performances of all his creatures, excepting the one example of total depravity—man.

But let this not trouble us. Like the orthodox interpretation of Scripture, so the orthodox interpretation of Nature may be far out of the way; and the readiness with which the world has accepted new views, when their correctness is beyond controversy, and yet kept its faith in the power, the wisdom, and the goodness of God, shows the truth of the following aphorism: "It is important not to confound the fundamental order of Nature, which is indeed immutable, with the ideas, more or less complete, which we entertain at a given time, respecting the manner in which that order is manifested."

THE ROYAL INSTITUTION AND THE SOCIETY OF ARTS.[1]

By BERNARD H. BECKER, Esq.

COMMENCING with the nineteenth century, the Royal Institution, that stronghold of fashionable science in Albemarle Street, can claim for itself many of the most remarkable discoveries which have distinguished an era of unrivaled activity. It owes its origin partly to Sir Joseph Banks, but in a far greater degree to a more remarkable man. Benjamin Thompson, afterward Count Rumford, was a lineal descendant of one James Thompson, who figured at Charlestown in Winthrop's company in 1630. Born in his grandfather's farmhouse, he enjoyed the advantage of a good grammar-school education, and then advanced in the world by the steps familiar to this day in America, but almost unknown in Europe. He was apprenticed to an importer of British goods, was allowed to make small ventures on his own account, fancied that he had invented perpetual motion, took a great interest in questions relating to light, heat, and the wind, lost his place, and blew himself up with fireworks before the age of sixteen. At seventeen he was a dry-goods clerk in Boston, studied French during his evenings, and got himself an electrical machine with money earned by cutting and carting firewood. He then boarded for some eighteen months with a Dr. John Hay, and picked up a little anatomy, chemistry, surgery, and physic, and in 1771 went to Cam-

[1] Abridged from "Scientific London."

bridge, Massachusetts, to attend Winthrop's lectures on "Experimental Philosophy." He then, after the manner of his country, "taught school" at Wilmington; and afterward became master of a school at a place originally called Rumford, but subsequently rechristened Concord, when the disputes as to the State to which it belonged were finally settled, and it was ceded to New Hampshire for good and all.

Shortly before attaining the age of twenty, Thompson, a fine, handsome young man, married—or, to use his own expression—"was married by" Mrs. Rolfe, a wealthy widow of Concord. There was now no more occasion to "teach school," and Thompson hoped for leisure to pursue science vigorously; but the American Revolution breaking out, he speedily found his way to England, in 1778 was elected a Fellow of the Royal Society, and two years later became an under-secretary of State, and colonel of the king's American Dragoons. At the conclusion of the war he was knighted by George III., and, having met the Elector of Bavaria at Strasbourg, passed a considerable time in Munich, busying himself in improving the breed of cattle and in building workhouses, and it was in order to find the most economical method of lighting the workhouse in Munich that he initiated the series of experiments afterward embodied in a paper on "The Relative Intensities of the Light emitted by Luminous Bodies," read before the Royal Society.

Honors now fell thickly upon the successful American. In 1785 he was elected member of the Bavarian Academy of Sciences, and in the two succeeding years was made a member of the Berlin Academy of Sciences, and received the order of St. Stanislaus. Finally, Sir Benjamin Thompson became Lieutenant-General of the Bavarian Armies, received the order of the White Eagle, and was made a Count of the Holy Roman Empire.

After the death of his wife he traveled for sixteen months in Italy, and during his stay at Verona rebuilt the kitchens of the two great hospitals—La Pieta and La Misericordia. Seven-eighths of the firewood were saved, and his success in this enterprise appears to have greatly encouraged Count Rumford to pursue his investigations into the proper management of fuel. A curious essay written by him about this time contains the mixed philanthropic and philosophic germ of the Royal Institution. This is a "proposal for forming in London, by private subscription, an establishment for feeding the poor and giving them useful employment, and also for furnishing food at a cheap rate to others who may stand in need of such assistance, connected with an institution for introducing and bringing forward into general use new inventions and improvements, particularly such as relate to the management of heat and the saving of fuel, and to various other mechanical contrivances by which domestic comfort and economy may be promoted." This was followed by other essays on "Food and feeding the Poor," on "Rumford Soup and Soup-Kitch-

ens," and on "Chimney Fireplaces." The Rumford medal was now presented to the Royal Society "for discoveries tending to improve the theories of fire, of heat, of light, and of colors, and to new inventions and contrivances by which the generation, and preservation, and management of heat and of light may be preserved." The endowment of the medal consisted of £1,000 stock, and was, I may add, presented on the first award, in 1802, to its founder. Meanwhile Rumford went to Ireland and fitted up laundries and model kitchens, cottage fireplaces, and model lime-kilns; served in Bavaria, preserving by his firmness and skill the neutrality of that country; and finally determined to return to America, but was deterred from carrying out this project by his anxiety to launch the Royal Institution. In the mind of Rumford the dominant idea was originally that of bettering the condition and increasing the comforts of the poor. A society was formed for this purpose, and out of it sprang, from a proposal of Count Rumford, a scheme for forming a new "Establishment in London for diffusing the Knowledge of Useful Mechanical Improvements." The two great objects of the institution were declared to be, the diffusion of the knowledge aforesaid and the teaching of the application of scientific discoveries to the improvement of arts and manufactures in this country. To fulfill the first object were to be exhibited full-sized working models of fireplaces, kitchens, stoves, grates, boilers, coppers, etc., and smaller models of houses, bridges, spinning-wheels, and of all "such other machinery and useful instruments as the managers of the institution shall deem worthy of the public notice."

In order to carry into effect the second object of this institution—namely, "teaching the application of science to the useful purposes of life"—a lecture-room was to be fitted up "for philosophical lectures and experiments, and a complete laboratory and philosophical apparatus, with the necessary instruments, will be provided for making chemical and other philosophical experiments." On the 7th of March, 1779, a meeting was held at the house of Sir Joseph Banks, at which the list of original fifty-four proprietors and subscribers of fifty guineas was read. In addition to the names of Rumford and Banks are found on this list those of Angerstein, Joseph Grote, the Duke of Devonshire, Earl Spencer, Earl Holland, Lord Palmerston, the Earl of Winchelsea, and William Wilberforce. By the end of June, 1801, the Royal Institution had received upward of £20,000 in subscriptions. The site of four houses had been purchased in Albemarle Street, professors of chemistry, physics, and mechanics, had been engaged, daily lectures were delivered, a spacious chemical laboratory had been erected, workshops for making models had been built, and skilled workmen engaged for making apparatus and models of various kinds. Early in this year Count Rumford wrote to his daughter that the Royal Institution was "not only the fashion but the rage," and mentions incidentally that "we have found a nice, able man for this place

as lecturer—Humphry Davy." This "nice, able man" was the eminent philosopher destined to explode a great part of Rumford's scheme, his models, his fireplaces, his kitchens, his experimental cooking, and his experimental dinners. In 1802 Count Rumford forsook England for Bavaria—as it turned out, forever—and, like many other benefactors of his species, was considered a good riddance. So far as can be ascertained, the American-Bavarian Count was offensively dictatorial in his manner, and exasperated those whom he did not succeed in crushing. Having shaken off Dr. Garnett, the first Professor of Chemistry at the Royal Institution, he engaged Davy as an assistant lecturer in chemistry, director of the laboratory, and assistant editor of the journals of the Institution. The future president of the Royal Society was granted a room in the house, coals, candles, and a salary of 100 guineas per annum.

The first interview of Davy with Count Rumford was not very agreeable to the young chemist, then in his twenty-third year. The intensely juvenile air of the candidate, his almost provincial manners, and a slight Cornwall accent, sufficed to reduce the glacial count to a lower temperature than usual. With considerable difficulty Davy obtained permission to give a few lectures on the properties of gases. This, however, was sufficient. At the first lecture the variety and ingenious combination of his ideas, and the fire, vivacity, clearness, and novelty, with which they were expounded, enchanted the few who came to listen to the young lecturer, in whom they found united the power of poetry, oratory, and philosophy. The second lecture was crowded, and his course was obliged to be removed to the large amphitheatre, whither his fervid genius, and in some degree his youth and good looks, drew immense audiences. The ladies were charmed by the handsome young lecturer, and never tired of praising the beauty of his eyes, which they declared were "made for something besides poring over crucibles."

Before coming to the Royal Institution, Davy had already attained a certain celebrity by discovering the anæsthetic properties of nitrous oxide, and the period of his professorship was signalized by many brilliant discoveries. Named titular Professor of Chemistry in 1802, he only resigned the chair in 1813. He delivered his last lecture on the 9th of April, 1812, the day after he was knighted by the prince regent, and the day before his marriage with Mrs. Apreece, a wedding which put him in possession of a large fortune. The splendor shed upon the Royal Institution by the new Professor of Chemistry prevented the exhibition of any regret at the entire alteration of the original plan of the establishment. The Institution was no longer a popular school of technical science, but became almost the exclusive property of the higher classes. Ladies of the highest rank, and young noblemen, assiduously followed the lectures of Davy, while his researches in the laboratory produced the most solid results. It was

there that he discovered the laws of electro-chemical decomposition, and succeeded in decomposing fixed alkalies—that he established the true nature of chlorine and the philosophy of flame. The electric battery with which the separation of potassium and sodium was operated is still preserved in the Royal Institution along with other apparatus used by Davy. The delight of the investigator, on seeing the globules of the new metal start through the crust of potash and catch fire on contact with the air, was intense. "He could not contain his joy, and danced round the room in an ecstatic transport; it was only after a while that he recovered sufficient calmness to continue the experiment." An immense electric battery was now constructed, and this heavy artillery directed against resisting earths. The result of experiment was to add four new metals to the list—barium, strontium, calcium, and magnesium. On resigning the chair of chemistry, Davy declared that he only renounced teaching in order to devote himself to original investigation, but after this date his life was only marked by one great discovery—that of the safety-lamp which bears his name.

In the year marked by the rising of that brilliant star, Sir Humphry Davy, the directors of the Royal Institution made another great success by appointing to the chair of natural philosophy a man of transcendent genius, the celebrated Dr. Young. He was one of the few infant prodigies who have made a mark in after-life. At two years of age he could read. At four he could recite by heart numerous English and Latin poems, of which last, by-the-way, he did not then understand a word; but by the age of fourteen he had learned—besides Greek and Latin—French, Italian, Hebrew, Persian, and Arabic. His passion for learning was immense, and his talent for overcoming difficulties astounding. On reaching man's estate he was an accomplished linguist, a brilliant mathematician, a botanist, a skillful musician, a neat turner, and a daring circus-rider. This universal genius did not remain long at the Royal Institution, but yet had time to deliver a notable course of lectures on "Natural Philosophy" before his retirement, when his place was occupied by Dalton. The famous author of the "Atomic Theory" was surprised, like other people, at the youthful appearance of Davy, and writes, characteristically enough: "He is a very agreeable and very intelligent young man, and we have extremely interesting conversations of an evening; his principal defect—as a philosopher—is that he does not smoke."

Although in the foremost rank of scientific men, Dalton was far from achieving great success as a lecturer, being almost utterly devoid of the fluency and power of illustration possessed in such a remarkable degree by Davy and Faraday. A most amusing account was given by Babbage of the incidents attending the presentation of Dalton at court. Firstly, he was a Quaker, and would not wear the sword, which is an indispensable appendage of ordinary court dress.

Secondly, the robe of a doctor of civil law was known to be objectionable on account of its color—scarlet—one forbidden to Quakers. Luckily, it was recollected that Dalton was afflicted with the peculiar color-blindness which bears his name, and that, as the cherries and the leaves of a cherry-tree were to him of the same color, the scarlet gown would present to him no extraordinary appearance. So perfect, indeed, was the color-blindness, that this most modest and simple of men, whose only pleasures were a pipe and a game of bowls, after having received the doctor's gown at Oxford, actually wore it for several days in happy unconsciousness of the effect he produced in the streets. The inventor of the calculating-machine, having offered to present his Quaker friend, was evidently in a state of fussy excitement about the result of the experiment. Poor Dalton was compelled to rehearse thoroughly the ceremony of presentation by the inexorable calculator, who—having found the chances in favor of a *faux-pas* to preponderate—was in a dreadful "taking" on the eventful day. The calculator was completely wrong. The king addressed a few remarks to Dalton, who replied in fitting terms, and the tribulation of Babbage was over.

While the claims of science were amply supplied by the genius of Dalton, Young, and Davy, literature and moral philosophy were intrusted to no ordinary hands. During the years 1804–'6, the town-talk of London was divided between young Roscius, the youthful tragedian, and the lectures on moral philosophy delivered by the Rev. Sydney Smith, who, forty years after, said, "I did not know a word about moral philosophy, but wanted two hundred pounds to furnish my house. My success was prodigious." The "loudest wit I e'er was deafened with" probably exaggerated his ignorance of his subject, as he had passed five years at Edinburgh, and had opportunities of hearing Dugald Stewart and Thomas Brown; but in any case the lectures were a certain success in the hands of the eloquent preacher, who, if himself knowing little about moral philosophy, addressed an audience which knew nothing at all. Of very different calibre were the lectures on poetry delivered by Coleridge. It will be recollected that it was in these famous discourses that the author of "Christabel" promulgated those views which have since spread far and wide, and will probably hold their ground when the ephemeral opponents of Shakespeare, and worshipers of a second-rate poet like Schiller, have for long ages been consigned to oblivion.

On the retirement of Davy, in 1813, William Thomas Brand, a distinguished chemist and Copley medalist, was nominated to the chair, which he so admirably filled for forty years. Meanwhile, a young man whose achievements were destined to invest the Royal Institution with peculiar glory had, in a manner of speaking, received the mantle of Davy. Michael Faraday was born at Newington Butts, of poor parents. His father was a farrier, of whom—to the great

sorrow of Prof. Tyndall—his son could never call to mind a single trait of intelligence. The boy was apprenticed to a bookbinder, but in his leisure moments learned "a little chemistry and other parts of philosophy." He had so far advanced as to construct for himself an electrical machine, when his master happened to show this specimen of ingenuity to one of his clients, Mr. Dance, who obtained permission for the apprentice bookbinder to be present at the last four lectures of Davy. The youth listened attentively, and made such notes that he was enabled to write a report of the lectures, which he sent to Davy, with a modest request that he might be employed in the laboratory of the Institution. Davy was struck by the clearness and exactitude of the young bookbinder, and gave him, at the commencement of 1813, the post of laboratory assistant. Toward the end of the year he accompanied Davy abroad, as his assistant and secretary. Returning to London in 1815, he recommenced his duties in the laboratory of the Institution, was appointed director of the laboratory in 1825, and two years later became one of the regular professors of the Institution, where his scientific researches, like those of Davy, were made at the cost of the society alone, without any assistance on the part of the state.

Among the many achievements of Faraday are the demonstration of the condensability of many gases, and his investigations into the reciprocal relations of heat, light, magnetism, and electricity. Not the least noble quality of this remarkable man was his marked preference of a purely scientific career over the acquirement of wealth. With the reputation acquired by the year 1832, he might have made several thousands a year by ordinary professional work, but, considering all the time not actually devoted to experiment or to demonstration as a sacrifice of original investigation, Faraday lived and died poor in the world's goods.

At the present day the Royal Institution maintains its renown—thanks to Prof. Tyndall, who, by his work on "Heat considered as a Mode of Motion," has proved himself no unworthy successor of Davy and Faraday. The late president, Sir Henry Holland, was, on his decease, replaced by the Duke of Northumberland, whose keen interest in scientific inquiry is well known. The important office of Treasurer and Honorary Secretary—on which to a great extent the success of the Institution depends—is now ably filled by Mr. W. Spottiswoode.

The Royal Institution, in addition to the attractions of its lectures, possesses a model-room, a newspaper-room, a reading-room, and a library of 36,000 volumes, presided over by Mr. Benjamin Vincent.

As might be expected in a highly-fashionable institution, membership is not acquired at a cheap rate, but candidates who are proposed by four members are immediately admitted to the privileges of the Institution, and pay on election ten guineas (five guineas as an admission-fee, and five guineas as the first annual payment). This

payment secures admission to all lectures delivered in the Institution, to the libraries, and to the weekly evening meetings, with certain other privileges—such as the right of admitting two friends to the Friday evening meetings—a privilege often abused on occasions when a lion of unusual magnitude is about to roar. An inferior kind of member is the annual subscriber, who enjoys most of the privileges above named, with the exception of admission to the weekly meetings, from which sublime gatherings he is excluded. Other persons are suffered to subscribe to the afternoon lectures at the very moderate price of two guineas for all courses of lectures from Christmas to midsummer, but are not allowed to show themselves elsewhere than in the lecture theatre, and never there on a Friday night.

This weekly meeting is a wonderful combination of science and society, of physics and fashion, albeit once in a while a printer or photographer manages to obtain permission to dilate on the excellence of his wares, and to thus advertise himself. Nevertheless, in spite of an occasional drawback of this kind, the Friday evening lectures are of sufficiently high class to please all but a purely scientific audience. It is clear that to gratify the members—who are, after all, mere flesh and blood, and not philosophical abstractions—concessions to popular taste and feeling must occasionally be made. Thus, while all may equally enjoy a lecture on the "Acoustic Transparency and Opacity of the Atmosphere"—a subject which, in its practical relation to fog-signals, is full of general interest—those of a higher and drier turn of mind experience ineffable delight when Prof. Sylvester holds forth on the conversion of circular into parallel motion; while the noble army of simple lion-hunters rush not only to hear, but to see, Sir Samuel Baker. On this particular night I find all the approaches to Albemarle Street blocked by carriages, and on making my way into the Royal Institution find the theatre fully occupied at a quarter-past eight o'clock, or three-quarters of an hour before the time of the lecture. With the exception of a few seats reserved for the two Boards of Managers and Visitors, the hall is crowded to the ceiling, every avenue being already jammed with a dense mass of people, among whom gay opera cloaks and *Angot* caps largely predominate over black coats and showy shirt-fronts. A few young men are visible, but, after standing about for a while, and finding it impossible to approach their far friend, these youths vanish through the crowded door-way and are seen no more, thus leaving the entire field clear to the British matron, who prevails to-night to an extent that would have struck terror into the soul of poor Nathaniel Hawthorne. There is no inconsiderable amount of crowding and pushing in this elegant throng, and I am forcibly reminded of the saying of a certain philosopher—who has seen men and cities, and the customs of them—that "a well-dressed crowd is a rude crowd."

So thoroughly and completely packed is every bench, step, and

door-way, that it occurs to me as a piece of singular luck that no formidable philosophic apparatus is necessary for a dissertation on the "Slave-Trade of the White Nile," as the space often occupied by Prof. Tyndall's tubs is packed full of chairs, to the great relief of a number of ladies. Sir Samuel Baker delivers his views on the "Slave-Trade" to an evidently sympathetic audience, easily put into good-humor by being told that England was the first nation to set the world the noble example of liberating her slaves—a statement, by-the-way, not precisely accurate, inasmuch as in 1780 was passed an act for the gradual extinction of slavery in Pennsylvania, an example followed four years later by the States of New Jersey and Connecticut, and in 1793 the French abolished slavery in Hayti, forty years before its abolition in our West India colonies. No doubt, to those who had never heard much about slavery, the remarks on its cruelty and injustice were interesting enough, but I, *infelix*, have had my ears too often pierced by shrill American voices, raised to shrieking pitch on this subject, during "the late trouble." Sir Samuel Baker is an excellent advocate for a new crusade against slavery, and produces ample evidence as to the atmosphere of general rascality evolved by slave-holding and slave-dealing, but his arguments, though true enough, are not very new. The lecturer, however, possesses the excellent gift of carrying his audience along with him, and sends them home happy in the conviction that they have assisted at an anti-slavery demonstration.

The claims of science are amply vindicated on the following Friday by Dr. Wright, an experimentalist of known boldness, who delivers a discourse on the "Chemical Changes accompanying the Smelting of Iron in the Blast-Furnace." Dr. Wright has enjoyed the advantage of pursuing his investigations in concert with Mr. Lowthian Bell, a gentleman well known by his inquiries into the chemistry of the blast-furnace, as well as by his office as President of the Iron and Steel Institute, and his gigantic enterprises in the production of iron and chemicals. Although of little interest to the general public, this lecture commands a good attendance of experts, who follow Dr. Wright very attentively through his exposition, and endure, without a murmur, an atmosphere heavily charged with noxious gases.

I have already observed that, in addition to the Friday evening meetings, where lions of the first magnitude roar by turns, several courses of afternoon lectures, in which actual teaching is combined with attractive experiments, are given during the session. These lecturers and their subjects attract audiences of varying strength. Looking in, one afternoon, to hear a lecture on Paleontology by Prof. Duncan, I find the theatre but thinly attended, in spite of the interesting character of the lecture, and its eloquent treatment by the expositor. This apathy may perhaps be explained by the difficulty of inspiring ordinary human beings with a taste for science, pure and simple; as I well recollect that, when—at the dawn of the Darwinian

system—paleontological lectures were unavoidably associated with the controversy initiated by that philosopher, every lecture directly or indirectly bearing on the theory of development commanded a numerous and fashionable audience. Attentive listeners sought, in the discourses of Prof. Owen, for facts and deductions more or less damaging to the bold theory advanced in the now famous "Origin of Species by Natural Selection." But the uproar occasioned by the "Essays and Reviews," and Mr. Frederick Harrison's review of the reviewers in the *Westminster*, has nearly subsided, and the polemical element has faded out of geological discussion. Denuded of its controversial spice, paleontology no longer possesses its whilom attractiveness, and the audience of to-day is apparently composed of those who care for the subject for its own sake alone. Prof. Duncan is discoursing on that friend of my youth, the *ichthyosaurus*, and in a few neat and graphic sentences describes the manners, customs, and peculiar structure of the great fish-lizard, with whale-like body, crocodile head, and monstrous saucer-eyes. The *plesiosaur* with the outline described by the late Prof. Buckland as that of a "turtle with a serpent pulled through it" next engages attention, and is described very graphically as a "'longshore-man" of the diluvial period, a prowler on the edges of the great deep, and a snapper-up of unconsidered trifles. *Plesiosaurus* disposed of, the inevitable *pterodactyle* turns up, the flying lizard of predatory habits, the possible progenitor of birds, and the certain original of the heraldic dragon and griffin. The shape of the head and the gradual adoption by this grewsome creature of a breastbone, give still more coherence to the theory that *pterodactyle* is a lizard which is rapidly making up his mind to become a bird. These particulars, and a dissertation on coral islands, make up the body of an interesting lecture, which fails, however, to warm the audience into enthusiasm. Perhaps people don't care for coral islands, or mayhap, to parody a line of Mr. Bret Harte —"the *pterodactyle's* played out."

On another raw afternoon, about 3 P.M., I betake myself to Albemarle Street, and become the spectator of a widely-different scene. The theatre is already full of eager visitors and thirsters after science, when elucidated by those brilliant experiments which excite the admiration and envy of Prof. Tyndall's imitators—I had almost written rivals, forgetting that in this country, and in his own particular line of physical demonstration, Dr. John Tyndall, F. R. S., philosopher and cragsman, has no rival. At a three-o'clock lecture many ladies are, of course, present, in all the variety of gorgeous array at present infashion, for, however severe may be the mental attributes of these fair students of physical science, no sternness is ever visible in their outward appearance. Pending the arrival of the Professor of Natural Philosophy, these young ladies are chatting pleasantly among themselves. Are they talking science, I wonder, or discussing

the merits of the Leonardo da Vinci hat, or the grace and style communicated by the Norwegian waist-belt, with all sorts of turnip watches and other quaint odds and ends dangling from it? Do they know much about liquids and gases, or have they come to learn? Verily, I know not. The well-known lecture-table is covered with apparatus, and a huge bath-tub occupies a considerable space. Mr. Cottrell, the laboratory assistant, is very busy, till, punctual to the stroke of three, a tall, slender man, of undeniably Scottish aspect, steps to his place behind the lecture-table, and a murmur of applause proclaims the satisfaction of the audience at the arrival of the successor of Faraday. The lecture, interesting in itself, is rendered doubly so by numerous and beautiful experiments, which succeed with infallible certainty. Perhaps the listeners to Prof. Tyndall are accustomed to see his experiments "come off" in this way, but the traveler in search of science often sees experiments—chemical, physical, and others—break down with provoking perversity. No approach to any thing like failure occurs to-day, and the applause is great on the light-carrying power of water being demonstrated by an experiment of singular beauty. The prescribed hour appears unnaturally short when the clock strikes, the lecture is closed by a short sentence, and, amid a mighty rustling of silks, the audience prepares to depart. For a few minutes a talkative crowd blocks up the wide staircase and hall, and a sort of scramble takes place for the carriages of which Albemarle Street is full. Fashion takes its departure, and, having laid in science enough to last for a week, leaves the professor to enjoy himself in his admirably-appointed laboratory.

As I wend my way homeward, I reflect on the large amount of good solid work that has been done in the laboratories of the Royal Institution during the last seventy years, and on the effect produced by the dissemination of scientific knowledge among the upper classes. As a firm believer in the doctrine that all revolutions in taste must take their inception above and gradually percolate through the several strata of society, I keenly sympathize with the efforts of the Royal Institution toward inoculating a love for scientific investigation. Following the example of the sun—which first illumines the mountain-tops, and later in the day penetrates into the deeper valleys—knowledge, striking first on the upper social regions, gradually descends, until all sorts and conditions of men are irradiated by its peaceful light.

Like its younger sister in Albemarle Street, the Society of Arts is a notable instance of that drifting faculty which exercises so great an influence on all human institutions. Launched with widely-differing objects on the stream of events, these societies have in a certain measure displaced each other. The Royal Institution, now devoted to literature, and in a greater degree to pure science, was originally

founded to promote those objects which have been fostered by the elder society, which, drifting away from ART in its highest sense, has taken in hand industrial art and applied science. One single comparison will demonstrate my meaning. In the beginning of the century—under the auspices of Count Rumford—the Royal Institution undertook to improve the dwellings of the working classes, to warm and ventilate workhouses, hospitals, and cottages, and to exibit and patronize improvements in the economical consumption of fuel and the teaching of culinary science. In the present year the Society of Arts, founded originally to encourage young artists, has offered premiums for the best kinds of culinary and domestic warming apparatus, and has directly fostered attempts to instruct the people of England in the best methods of preparing food.

The Society of Arts has now existed for a hundred and twenty years, and owes its foundation to Mr. William Shipley, a landscape-painter, who, from a "well-grounded persuasion of the extensive utility of the art of drawing to this nation, erected the Academy in the Strand, opposite to Exeter Change." By the efforts of this gentleman a meeting was held in 1754 at Rawthmell's coffee-house, to consider the propriety of establishing a "Society for the Encouragement of Arts, Manufactures, and Commerce."

It was resolved to bestow premiums on a certain number of boys and girls, and an advertisement was issued accordingly. The industrial element, however, was not lost sight of, as, while a number of drawing prizes were advertised, premiums were offered for the discovery of cobalt in England, the growth of madder, and the manufacture of buff leather. The primary object was the encouragement of art, but the view taken of the "polite arts" was a sufficiently wide one, inasmuch as the premiums offered under this head were ultimately grouped under 196 classes. Many prizes were awarded for drawing, and among the recipients was Richard Cosway, who afterward became a Royal Academician, and a portrait-painter of repute. It was soon found necessary to confine the objects of study to certain models, and, as no public museum or National Gallery then existed, individual collections, such as that formed by the Duke of Richmond, were selected for study.

On the consolidation of the Society, the artists of London applied for permission to hold an exhibition in the Society's rooms. This permission was granted, and exhibitions continued to be held for several years. This annual inspection of the works of rival artists, who formed themselves into separate bodies, excited emulation, directed public attention toward their works, and ultimately secured for them the royal patronage and protection. These first exhibitions of pictures by native artists in the rooms of the Society of Arts may, therefore, be regarded as the origin of that exhibition of the Royal Academy which now forms one of the great events of the London season.

While the encouragement of art—pure and simple—thus formed the main object of the Society, investigation was directed toward many practical subjects related to the central idea. Endeavors were made to improve the materials employed by artists, and much attention was devoted to the various engraving processes as they gradually came into vogue. Wood-engraving, aquatint, and mezzotint, were the subject of anxious care, as were improvements in pigments, oils, and varnishes.

Bronze casting and chasing, iron-castings, and artistic metal-work, were also encouraged, and at a later date, when Alois Senefelder, an actor of Munich, discovered lithography, the new art was first introduced to this country under the auspices of the Society of Arts. Steel engraving was also first taken seriously in hand by Mr. Charles Warren, chairman of the Fine Arts Committee, who, at the suggestion of Mr. Gill, chairman of the Mechanics Committee, adopted a new method of treating steel plates. Previously to this, many attempts had been made to engrave on steel. Albert Dürer is said to have etched on steel, and there are four plates etched by this artist, impressions of which exist in the British Museum, and which in all books of art are recorded as having been executed on steel. In the attempts to revive this art, pieces of saw-blades were selected as the most promising material, but these efforts were attended with very little success. A Mr. Raimbach then endeavored to engrave on blocks of steel, but without achieving any material advance. Mr. Gill now drew the attention of Mr. Warren to the method employed at Birmingham in the manufacture of ornamental snuffers and other articles of cast-steel. The process employed at Birmingham was "to subject the steel, after having been rolled into sheets, to the process of decarbonization, by means of which it was converted to a very pure soft iron, being then made into the required instrument or other article. The ornamental work is engraved or impressed on the soft metallic surface, which, by cementation with proper materials, is again converted superficially into steel. Mr. Warren modified this process, and obtained thin plates of steel capable of being acted upon by acids and cut with the graver, without destroying the cutting edge of the tool—as was the case with the saw-blades. The resulting plate yielded a greatly-increased number of impressions." When brought to perfection, steel plates were found equal to the production of ten or twelve times the number of impressions yielded by copper plates. Capital was invested in the production of works of a high class, with the effect of spreading far and wide through the country myriads of prints calculated to elevate and improve the taste of the people. This process of conversion and reconversion of steel was soon afterward applied by Perkins to the production of steel rollers. These were first softened and then pressed into the engraved surface of a hardened steel block, and having acquired a design in relief were themselves hardened in their turn, and

by being applied to softened steel plates produced almost indefinite multiplication of the original engraved plate. For commercial purposes this invention proved of immense value in the production of bank-notes, receipts, and postage-stamps.

To ignore the exertions of the Society of Arts in the direction of agriculture, and especially arboriculture, would be to omit an important page in its history. The introduction of new varieties of grasses and roots was sedulously encouraged, while drill-ploughs, the drainage of land, root-slicers, chaff-cutters, scarifiers, reaping-machines, and means of harvesting hay and corn in wet seasons, were all subjects of premiums. Big things and little things came in for their share of attention. In the early days of the Society sheep were marked with tar, to the great loss of wool-growers. The Society sought strenuously to modify and improve the mode of marking sheep, and meanwhile instituted a crusade against that bold invader, the Norway rat, who had recently overrun the country.

The preservation of timber was an object of earnest solicitude. In this age, when coal has effectually displaced wood as a heat-producer, and iron has been successfully applied to the construction of houses and ships, it is difficult to realize the anxiety of our forefathers at seeing whole forests destroyed for smelting purposes. For a long time past the work of destruction had been going on, when the Society of Arts stepped in to advocate the planting of trees on a large scale. The production of oak was a special object of the Society's attention, the planting of acorns was carried on to a very large extent, and gold medals for raising that description of timber were awarded to many noblemen and gentlemen, among whom were the Earl of Wilton, the Marquis of Tichfield, Mr. Morse, Mr. Curwen, and others. The cultivation of the ash—for which the Bishop of Llandaff received a gold medal—of the Scotch fir and larch, and of fruit-trees generally, received active encouragement. Under the auspices of the Society millions of trees were planted, to the enrichment and adornment of many previously-barren slopes. It is worthy of remark that to a neglect of these precautions is assigned an actual change of the climatic conditions of parts of Italy, and that the reduction of the Arno to an insignificant stream is ascribed to the reckless denudation of the mountains among which that historic river takes its rise. Travelers in Switzerland also have not failed to observe in the side valleys many relics of ancient mines, deserted, at last, because all the wood within carrying distance had been recklessly destroyed without any attempt being made to replace it by planting.

Considerable effort was devoted to encouraging the introduction and culture of spices into the British possessions. The cinnamon-tree was introduced into Jamaica; the nutmeg-plant into St. Vincent; the clove-tree into Trinidad; the mango and the bread-fruit tree were also planted in the West Indies. Attention was also directed toward such

imports as were capable of discovery, manufacture, and culture, at home.

Cobalt was discovered in Cornwall; buff leather and its manufacture improved; copper and brass vessels were tinned; and hemp, flax, and madder, were cultivated for the use of our manufacturers. "Sawmills were built; our fish-supply improved; and the curing of fish encouraged. Upon the fish-trade alone the Society expended many thousands of pounds, and succeeded in establishing a regular supply to the London markets."

During the greater part of its career the Society thus addressed itself to the task of fostering the useful arts. One condition, however, was, in the early days of the Society, rigidly insisted upon. The inventor who sought to obtain recognition of his discovery was obliged to forego the idea of patenting his work. What was given to the world by the assistance of the Society of Arts was to be given freely and openly for the benefit of all. Although this principle would find many and eloquent advocates at the present day, a period intervened during which it was found necessary to make concessions to patentees. The introduction of steam as a motive power led to a sudden and immense development of mechanical ingenuity, and swelled the prospective reward of a successful inventor to such large proportions that it was no longer probable that men would work for honor and glory alone. Eventually patentees were permitted to read papers before the Society of Arts, which, during the greater part of a century, continued to take an active interest in advancing the interests of science, and in affording aid and countenance to the other societies of less catholic tendencies, which sprang rapidly into existence. As has been already pointed out, the Royal Academy in its youth owed much to the Society of Arts; and it is worthy of note that, not only was the first exhibition of the works of rival artists held in the Society's rooms, but the first collection of photographs exhibited there in 1853. The Society still maintains a liberal tone, and is generous enough to grant the use of its handsome room to many societies for the purpose of holding their various meetings.

If the Society in the Adelphi merit a place of honor as a promoter of other societies, still more does it demand notice as the mother of exhibitions. Its exhibitional maternity was shown in this wise: In the year 1841 the Society of Arts, like many other originally active bodies, had shown signs of falling into decrepitude. For many of the purposes for which it was originally established, its office had been filled by other institutions, which, being less expansive in their views, appeared likely to act toward the mother-society like young ducks hatched by a barn-door hen, and to take to the stream of the future without consulting the feelings of their foster-parent. The Society was obviously falling into the sere and yellow leaf, and it was clear that something had to be done to rejuvenate it. A committee was

appointed to revise the working of the Society, and that body recommended that a council to manage the affairs of the Society should be instituted. The committee in its report also gave expression to the conviction that "the Society cannot continue to exist on the plan of proceeding which is at present pursued," and that "the object of the Society is the promotion of the useful arts rather than the personal gratification of the members." It was further recommended that six committees should be established, of five members each, and many other valuable pieces of advice were tendered, but nothing came of all this for the time being. At length, however, measures were taken for obtaining a royal charter of incorporation, finally granted in 1847, and in the mean time it was proposed that an exhibition of English industry, analogous to those held abroad, should be instituted. The first action taken in this direction was an offer of special prizes for articles of manufacture, and a special fund was obtained for this purpose by private subscription. It was deemed necessary to stimulate the makers of English pottery to efforts toward an artistic combination of form and color. A committee of artists was appointed to adjudge the prize for a tea-service, and this was awarded to a set designed by "Felix Summerly," and manufactured by Messrs. Minton. The identity of "Felix Summerly" was then disclosed, and the Society's silver medal was presented to Mr. Henry Cole (who has since received the Companionship of the Bath), on the 12th of June, 1846. From this date a notable change came over the constitution of the Society. Yearly exhibitions were held. It is true that these were of a sectional character, and only proposed to illustrate certain branches of English industry; but it is not the less true that they were the immediate precursors of the great Exhibition of 1851. Prizes for modern industrial art were offered, and were eagerly competed for. Manufactures and artistic productions were got together at great expenditure of cash and industry, with the effect of rapidly increasing the number of members. In 1847 the members of the Society numbered scarcely five hundred; but within three years these numbers had tripled. But, in 1849, there were "croakers" in the camp. Not a few of the ruling spirits were inclined to "look back from the plough." As an instance of this may be quoted a recommendation of the Finance Committee of 1849, that "the exhibitions be discontinued," and another, passed in December of the same year, that "it is expedient to reconsider the policy of an Art Manufacture Exhibition in the year 1850." But the advanced spirits of the Society were not to be balked. Against the council of the ancients a formidable opposition was organized. Mr. Cole resigned his seat on the council, and, biding his time till the general meeting, effected a noteworthy *coup d'état*. On election-day the reactionary party were ousted by an immense majority, and an entirely new council elected. The Exhibition of Ancient and Mediæval Art was duly held, and resulted in a splendid success, and a com-

plete revolution of the financial condition of the association. In 1850 the debts of the Society amounted to £2,402, an amount that was reduced in 1851 to £1,696, since when the Society has become not only solvent, but possessed of a large accumulation of capital, which—in the opinion of many of the members, now amounting to over 3,000—it is somewhat chary in dispensing. This great storm, which completely altered the condition of the Society of Arts, and culminated in the Great Exhibition of 1851, can thus be distinctly traced to Mr. Felix Summerly's "teacup."

The merit of initiating the idea of an international exhibition has been often warmly contested, but there is no longer any doubt that the original proposition was made to the committee of the Society of Arts in 1844, by Sir William Fothergill Cooke. There is no question that the idea of this gentleman was clearly that of an international exhibition, at that time declined by the committee of the Society of Arts, but at a later period adopted by that body with the sanction and coöperation of the late prince consort.

In the month of June, 1849, the secretary, Mr. J. Scott Russell, stated at the annual meeting, in the presence of the late prince consort, that, owing to the yearly increasing success of the Society's exhibition, the council had no doubt of their being able to carry out the plan originally proposed for holding a great national exhibition of the products of British industry in 1851. This statement led to frequent communications between his royal highness the president and various members, with the ultimate result of expanding the plan to international dimensions. The prince consort, as president of the Society, brought the scheme officially under the notice of the Government; but in the mean while the Society of Arts was not idle, and had already entered into a contract for building a convenient edifice, when a royal commission was issued. Mr. Scott Russell and Mr. (now Sir) Stafford Northcote were appointed secretaries. An executive committee was formed, consisting of "Henry Cole, Charles Wentworth Dilke the younger, George Drew, Francis Fuller, and Robert Stephenson, with Matthew Digby Watt as secretary." Meanwhile the Society of Arts had organized the financial arrangements necessary for carrying out the scheme, but the immediate connection of the Society with the exhibition now came to an end; the child had outgrown its nurse, and required nothing short of a royal commission to manage it. How well the Exhibition of 1851 was managed, and how, after the final adjustment of accounts, a surplus of £186,438 18*s.* 6*d.* remained in hand, are now matters of history, as well as the expenditure of that sum as part of the money devoted to the purchase and development of the Gore House estate.

Since the launching of the Great Exhibition, the Society of Arts has done much good work in promoting industrial art and encouraging inventive genius. It is true that much of its work has been taken out

of its hands by the societies and museums to which it has given rise. Among these is the Photographic Society, whose inception was due to the exhibition organized by Dr. Diamond. The South Kensington Museum itself may be fairly regarded as an offshoot of the Mediæval Exhibition, while the Government Department of Science and Art is directly descended from the parent body. But the mission of the Society is not to repose on its laurels. It comes to the fore with a formidable list of premiums, at the head of which is a series of gold medals and prizes of £50 for improved cooking and warming apparatus; £500 are devoted to this purpose, and have been placed at the disposal of the Society by a single member. A large number of prizes in money, and many gold and silver medals, are also offered to inventors. Much interest is excited at the present moment concerning the award of the Albert Gold Medal, a prize established in memory of the late prince consort, to reward "distinguished merit in promoting arts, manufactures, or commerce." This medal was first presented in 1864, to Sir Rowland Hill, K. C. B., in 1865 to the late Emperor of the French, and in 1866 to Faraday. Since then, this distinguishing mark of the Society's appreciation has been conferred on Wheatstone, Whitworth, Liebig, Henry Cole, Henry Bessemer, and has this year been awarded by the council to Dr. C. W. Siemens, "for his researches in connection with the laws of heat, and the practical applications of them to furnaces used in the arts; and for his improvements in the manufacture of iron; and generally for the services rendered by him in connection with economization of fuel in its various applications to manufactures and the arts."

For some years the Society's examinations, conducted through local institutions about the country, have assisted the spread of general education, and, now that this work is being more completely executed by the university local examinations, the Society has set on foot a scheme of technological examinations, which it is hoped may bear good fruit.

THE FIRST TRACES OF MAN IN EUROPE.

By Prof. ALBRECHT MUELLER.

TRANSLATED FROM THE GERMAN, BY PROF. JOSEPH MILLIKIN.

I.

IN a fine contrasting of Europe's wealth of historic memorials with his own country's yet new civilization, Washington Irving says of the former country, "Its every stone is a chronicle."

The remark is true, applied, as he meant it to be, to our older cities with their ancient edifices and defenses. But, belonging to a yet remoter past, are the remains of Roman and Celtic arts and architecture;

and in the pile-dwellings of our lakes and peat-beds we have relics of the Stone and Bronze eras, the beginnings of which lie beyond the reach of even tradition.

Nor is the limit yet attained. Thanks to the discoveries of the past few decades, we trace the existence of man back to a point antedating our earliest history by we know not how many centuries. Of this time, only a few bones and rudely-wrought stones are left as the witnesses—dumb, yet eloquent, and fulfilling in their way the saying, "If men hold their peace, the very stones will cry out."

The question was long since raised, whether traces of human existence had been, or were to be, found in the sand and gravel of the Post-Tertiary or Diluvial period, which immediately preceded the present. Some affirmed the finding of such remains in these, and the contemporaneous deposits of certain caves, while most geologists rejected such statements as erroneous, or, at best, unauthenticated, plausibly urging that ancient animal and recent human remains might easily have become intermingled. And such researches were discredited and discouraged by Cuvier's magisterial dictum, that man did not exist in the Diluvial period, and that it was, therefore, vain to look for evidences of his existence.

Some twenty years ago, however, M. Boucher de Perthes discovered a quantity of rude stone implements in the diluvial gravel-beds of Abbeville, in the valley of the Somme, in intimate connection with bones of mammoths. This discovery attracting much attention, in 1858 the French Academy of Sciences sent to the spot a committee of investigation, composed, be it not forgotten, of men utterly skeptical as to the fact at issue. This committee, strengthened by the accession of several English geologists, worked long and carefully at its task, and the Academy's discussions upon its reports were earnest and thorough; yet, the result was the complete confirmation of De Perthe's reputed discoveries, and of the conclusions he had drawn therefrom. Cuvier was confuted; the existence of man in the Diluvial period was established. Similar discoveries in the open country and caves of Germany, Spain, Italy, England, Belgium, and especially France, followed in rapid succession.

We cannot mention, much less describe, all the localities in which have been found the closely-conjoined remains of man and of animals, confessedly belonging to the drift or Diluvial period. We shall discuss only a few of the many cases, of which we may safely affirm that the often easy and common mingling of ancient with recent remains could not have occurred. To do this the more intelligently, we shall speak briefly first of the characteristics and deposits of the Diluvial and later prehistoric periods, and then of the human remains therein found.

THE DRIFT OR DILUVIAL DEPOSITS.—The bottom-lands of our new valleys, of the Rhine, for example, chiefly consist of widely-extended

deposits of loam, sand, gravel, and rocks, evidently brought from considerable distances by some vast current that once covered the lowlands, and even lesser hills; for, in the Rhine Valley this surface-layer is found at elevations of 300 to 600 feet above the present river-level. The bowlders are of various rocks that are not native to this region, but are found in the Juras, the mountains of the Black Forest, the Vosges, and especially the Alps, of whose mass these constitute a large proportion. A similar drift is found over the wide, rolling country between the Juras and the Alps, and indeed over nearly all the lowlands and valleys of Europe and the world. From the erroneous, but once universal belief, that it was produced by the Noachian Deluge, or the all-submerging flood of which the Sagas of so many nations are full, this deposit was early named the diluvium, or diluvial deposit. It consists, according to this view, of the detritus from mountain ranges, transported and scattered broadcast over lower levels by the Deluge.

This latest of geological formations rests upon the upper strata of the Tertiary, when they are present. In the Rhine Valley, however, it covers the Miocene or middle Tertiary; and in other regions, the chalk, the Jurassic, or even older formations. Upon the diluvium itself are built most of our cities, and in it will most of us be buried. The melted snows, the rains, and the waters of our streams, penetrate through its loose layers until the more impervious underlying clays (mostly Tertiary) arrest and hold them in readiness to supply our daily needs. The diluvium seldom yields much that is of mineral or industrial value, except the material of our tiles, brick, and mortar. In California, Brazil, Australia, and the Ural Mountains, however, its gravels are rich in gold, platinum, and jewels of various sorts, and in some localities tin-ores are found in it.

Geologists have been long occupied with the study of the producing causes of those vast floods, the effects of which are so strikingly seen in the pebbly plains and terraces of our river-valleys, and in the layers of sand and loam upon our uplands and hills. That there once were there masses of flowing water-currents, like, yet far vaster than, our present rivers, cannot be intelligently doubted. The absence of marine shells and the universal abundance of the remains of land-animals in the deposits in discussion forbid the belief that the sea covered our own and the adjacent continents during this latest of geological eras.

All the hypotheses advanced in explanation of the phenomena we have mentioned cannot be here adduced; we can only say that the great majority of recent geologists agree and assert that these immense streams were chiefly produced by the melting of snows and glaciers, that must then have extended not merely from the Alps and Pyrenees, as at present, but from the north, southward over a large portion of Europe; even the smaller ranges, such as the Vosges and Black Forest, then having each its glacier system.

Strongly in favor of this view are the erratic bowlders and blocks of stone, and the heaps and ridges of drift, so widely scattered over the mountains, plains, and valleys of Europe and North America, precisely similar as they are to those left by the retreat of the glaciers at the present time. And then, as now happens, the melting of floating icebergs, that were detached from the foot of glaciers as they reached the coast, strewed the ocean-bed with stones, gravel, and mud. The wide plains of Northern Germany are abundant in rocks and gravel from Scandinavia and Finland, for example. Our surface-deposits, therefore, are simply the detritus and *débris* of mountain-regions, transported thence by glaciers, and spread over our lower levels by the rivers that the melting of these glaciers produced.

This theory was first definitely propounded by Venetz, and has since been developed and verified by Charpentier, Agassiz, Forbes, and many others. Many geologists have opposed it from the first, but it may now be regarded as of practically universal acceptance, and as gaining constant confirmation from the immense number of facts annually observed and published.

The glacial theory implies the former prevalence in Europe and North America of a climate marked by much snow and rain, as well as ice; and this is confirmed by the characteristics of the fauna and flora of the time.[1] In addition to the waters produced by the melting of glacial masses then covering so large a portion of the Northern Hemisphere, the very great rainfall incident to such a climate would swell the volume of the great currents of the period—currents not of transient flow like mere mountain-torrents, or our local freshets, but that swept on for centuries or millenniums. Minor additional inundations, also, would result from risings and subsidences of the earth's surface in given localities, from the damming of the waters in the valleys by glaciers and avalanches, from the sudden emptying of mountain-lakes thus formed, and possibly from earthquakes. It is to these various causes that we may attribute the washing out of the lower terraces of our present river-valleys.

The great currents by which we explain the various phenomena of the drift are due to the glaciers of this Ice period, then; and this suggests the further question, What produced the Ice period itself, the long-prevailing low temperature of regions now warm or temperate? A vast array of observations commends to the attention the following answer:

There was then a distribution of land and water upon the earth very different from the present, and, as the result of it, a different system and direction to the currents of the sea and air. And there are

[1] Prof. Oswald Heer has given, in his "Urwelt der Schweiz," a description, at once scientific and entertaining, of the Swiss fauna and flora of the Drift period. In his valuable studies upon the diluvial flora, Count Gaston de Saporta concludes in favor of a climate in this period marked rather by extreme moisture than by extreme cold.

influences by which the climate of a given region is vastly controlled; that is, it is to the warmth of the waters of the Gulf Stream that the present mildness of the climate of the islands and coast-countries of Northern Europe is owing.

Adhemar has not been without followers, indeed, in the attempt to prove that the low temperature of the Ice period was due to astronomical rather than terrestrial causes—namely, to the change, in periods of 21,000 years, of the obliquity of the earth's axis to its orbit, and the still slower change in the eccentricity of that orbit itself. From the coöperation of these two causes, it is said the winters of either hemisphere would become longer and the summers shorter, and *vice versa;* and so on, in alternate periods. For example, the earth's axis reached the position most favorable to the climate of the Northern Hemisphere in A. D. 1248, since which time we have been advancing toward a new Ice period; whereas, antarctic regions then passed the point of greatest intensity of cold. Even the relative distribution of land and sea, it is affirmed, would be changed by these alternating accumulations and diminutions at either pole. To all this, we can here merely reply that if these astronomical facts have any influence whatever upon the earth's climate, we are wholly ignorant as to its amount; and since Herschel's time astronomers have been disinclined to ascribe to them any considerable share in the production of climatic variations.[1]

But there is abundant evidence that during the Drift period there took place extensive and considerable elevations and subsidences of the earth's surface. Such elevations are still going on, as witness the rise of the coast-terraces of Scotland, Sweden, Norway, Sardinia, Sicily, and other lands, to a height far above the present sea-level. Confusion here is easy, however, and it must not be forgotten that the retreat of the shore-line would be apparently and practically an emergence of the land, although the latter remained fixed all the time; and curiously, apparent encroachments of the sea upon the shore may be an actual subsidence of the shore itself.

A study of the drift deposits, and the organic remains found therein, compels the belief that at one part of that period the lowlands of Europe—i. e., Holland, the plains of Northern Germany, and parts of Russia, Great Britain, Denmark, Sweden, and Norway—were covered by the North and Baltic Seas, which, thus united and enlarged, extended southward through Russia and Siberia, and possibly connected the Black and Caspian Seas. The Desert of Sahara was also under water, as Desor and Escher show. The shells of marine species yet mostly extant, now found in the extensive lowlands of North America, show these also to have been submerged.

In an earlier epoch of the Diluvial period, however, that is, previous

[1] The scientific reader need not be informed that though Adhemar is not followed as to all details, many of the best modern (especially English) scientists agree in ascribing a prominent influence to these astronomical factors in the production of climate.—TRANSLATOR.

to the time of the above-mentioned submergence of so much of Europe, the countries mentioned were so high above the sea-level of the time that the bottom not only of the Straits of Dover but of a large portion of the North and Baltic Seas was dry ground. These waters have a depth even now of only some 200 feet—rarely of 250 feet—so that an elevation geologically very slight would expose the bottom of these shallow seas. So Ireland was then connected with Great Britain, and the latter with France; while Africa and Europe were joined by bridges of land, so to speak, e. g., by way of Gibraltar, and again by way of Sicily and Malta. As a natural result and confirmation of the latter instance, we find on these islands and the contiguous main-lands the remains of mammals peculiarly African, especially certain species of elephants. These strips of dry land divided the Mediterranean into several inland seas. If man existed in that remote epoch, as many arguments tend to prove, he could cross dry-shod between Africa and Europe, as did the animals just mentioned, and was a witness of a distribution of land and water in Europe and adjacent lands widely different from that of our day. There was also going on about him and beneath his feet the slow rising and sinking of vast continental and insular territories—processes requiring thousands of years for their accomplishment—and, if man's existence during them be admitted, constituting another proof of the great antiquity of the race.

It is to these slowly-effected but most important alterations in both the contour and relief of the surface that we must ascribe the great changes of the climate, not alone of separate localities, but of entire continents; and this conclusion we will finally use in explanation of the varied phenomena of the Ice period, with which we have specially to do. The Ice *period*, we have said; but, without attaching much importance to the astronomical influences previously mentioned, we are compelled to believe in a succession of Ice periods, the evidences of which are believed to be furnished in the several series of deposits that are assigned to corresponding epochs.

During the latter portion of the Diluvial period the earth acquired substantially the same relief as it has at present. The chief mountain-ranges, the Juras, the Vosges, the Black Forest, the Pyrenees, the Alps, etc., were then about what they are now, though somewhat higher relatively both to the sea-level and to the subjacent plains; for, by the operation of various natural forces, peak after peak has been either shattered and cast down, or slowly worn away, and their *débris*, carried down in the form of sand, gravel, or larger masses, have gradually but considerably raised the level of the valleys and plains.

We now proceed to consider the several subdivisions of the Diluvial and the Post-diluvial but prehistoric periods, and the traces of human existence belonging to each.

1. The Age of Mammoths.—The loëss, the layer of calcareous loam, sand, and gravel, with which our hills are covered, is full of the

shells of small land-snails, mostly extinct in this region,[1] though yet extant in high mountain-regions. So abundant are they as to give to this soil the popular name of "snail-shell soil." The preservation of animal and vegetable remains in the gravelly deposits of our lowlands is naturally rare, comparatively, they being, for the most part, soon destroyed in beds so loose and permeable by air and water. And yet in Germany, France, Belgium, England, Switzerland, and other parts of Europe, there are found, in this very formation, the bones and teeth of mammals, mostly of long-extinct species, the nearest congeners of which are now native either to Africa and Asia, or else to the colder parts of Northern Europe and America, and the higher Alps and Pyrenees. Bones of these same species, and hence of the same geological era, are found in numerous caves as well; some species, indeed, being almost wholly thus preserved. Among the better known of these caves we may cite those of the Suabian and Franconian Juras, and the Gailenreuther Cave, from which nearly every important cabinet of Europe has been enriched.

Prominent among the buried mammals of the drift are the mammoth (*Elephas primogenius*), the immense teeth and tusks of which are so often exposed by our river-currents, and during excavations for buildings, besides the many entire carcasses found in the ice and frozen soil of Siberia. In many of these latter cases, the skin, the hair proper, a reddish-brown, long, hairy wool, and a mane still longer, are kept in perfect preservation. The latest discovered of these was visited by the naturalist Schmidt, but the wild beasts had anticipated his coming, and devoured most of the flesh. Middendorf estimates the number found in that region at several thousands. Their tusks—considerably curved, and eight to ten feet in length—are in quantities still sufficient to be the staple of a not inconsiderable trade in ivory. Brandt believes the mammoth to have been somewhat larger than the East Indian elephant of to-day, with tusks of much greater curvature.

Next in size to the mammoth was a rhinoceros, characterized by two horns and an osseous nasal septum (*Rhinoceros tichorhinus*). Its teeth are often met with, and, some fifteen years ago, an almost entire and perfectly preserved carcass was found in the ice on the river Wilni in Siberia.[2]

Equally abundant with the remains of these two are those of the cave-bear (*Ursus spelæus*), which was about the match in size of the polar bear. It is found in the drift of the open country, and in the caves of the same age.

The peat-beds of Ireland yield entire skeletons of the giant-elk

[1] The reference is to the author's own picture of the Upper Rhine Valley, of course.—TRANSLATOR.

[2] Dana ("Manual of Geology," American edition of 1863, page 561) mentions a similar discovery in 1772, in the same locality. This species of the rhinoceros, like the mammoth, was protected by long, woolly hair.—TRANS.

(*Cervus ungaceros* or *C. Hibernicus*), the ten or twelve foot span of whose antlers must have put him to great disadvantage, and so proved one of the causes of his extinction.

Then comes the primitive ox (*Bos primogenius*), generally regarded as the progenitor of our present race of cattle, and found running wild in the forests of Germany as late as Cæsar's time.

The hippopotamus, found mostly in Italy and the south of France, is more rare. It is clearly allied to the species that now inhabit the tropics.

Remains of the cave-tiger or cave-lion (*Felis spelæa*)[1] have recently been found in various localities, though formerly but rarely.

Very significant as to the climate of Europe in this age is the presence of such species as the reindeer, musk-ox, and lemming,[2] which now inhabit only high northern latitudes, and of other species which are now peculiar to the moister heights of the Alps, e. g., the chamois, mountain-goat, and marmot. These were all once native to our plains and uplands.

The North American and European mammals of this period are very nearly identical. In place of and sometimes in addition to the mammoth, however, America had the equally immense mastodon (*Mastodon giganteus* or *Ohioticus*). Six almost perfect skeletons of it were discovered in Warren County, in Western New York, in 1845.[3] Their rude study of its remains suggested to the North American Indians the name of "Father of Buffaloes." The entire genus is wanting in the Diluvium of Europe, though several of its smaller species are represented in the Tertiary.

So far as is yet known, these are the most important contemporaries of primeval man in Europe. They are his competitors and enemies in the "struggle for existence," to meet which he must needs have had all his powers of body and of mind.

Now, it is important to remember that we find both these extinct animals' remains and man's bones and implements in the same deposits and caves of the Diluvial period; that is, that these animal and these human relics were contemporaneous, first as to their deposition, and

[1] The most recent studies ally it rather to the tiger than to the lion family.

[2] The Lapland or Norwegian marmot (*Myodes lemmus* and *M. torquatus*.)—TRANS.

[3] The author has fallen into confusion, certainly, as to localities, and probably as to facts: 1. Warren County, New York, is in the east-northeast part of the State; 2. I have searched vainly for mention of precisely such a discovery as the text describes. In 1844, and in Warren County, *New Jersey*, was found the skeleton of the young female mastodon now at Cambridge, Mass., with the skulls of four others.

Three perfect skeletons were afterward dug from swamps near Newburg, New York, and described by Dr. Warren in his splendid work, "The Mastodon Giganteus of North America," (second edition, Boston, 4to, 1855). These are the richest "finds" of which I have been able to find any account.

On the distinction between the mammoth and the mastodon, and their several species, characteristics, remains, and place in paleontology, and Indian legends, *see* a capital article in the *American Naturalist*," vol. ii., pp. 28, *et seq.*—TRANS.

secondly as to their unearthing and exposure to our observation. And how rapidly one such discovery follows another may be partly inferred from the fact that some years since a magazine[1] was founded in Paris, devoted to this special topic; many courses of lectures upon it were delivered in the various cities of Europe; and for some years international congresses have been annually held, and societies and periodicals established, for the discussion of it and cognate subjects. The literature of the subject is already voluminous.

Let us revert to M. Boucher de Perthes's discoveries in the drift of the Somme Valley. Begun in 1841, they were described by him in a work published in 1847—a work then too little appreciated. But when, in 1858, and in the same locality, he discovered a human skull and various stone implements, in intimate association with remains of the various animals of that period, the attention of the French Academy was aroused, and the study of historical geology received a new impetus. Some, indeed, see in the discovery of De Perthes only a cheat, or at best a mistake, and doubt the antiquity of this skull and its contemporaneousness with the animals found with it. The entire collection is proved to be of the same age, however, by the whole manner of the intermingling of human skulls, flint knives of unmistakable human workmanship, and animal remains; and the genuineness of De Perthes's discoveries and the validity of the inferences drawn from them are confirmed by many similar ones made since then in localities widely separated, both from that in which he worked and from each other.

What we said of the preservation of animal remains we repeat as applicable, in an even higher degree, to that of human remains, in *débris* so found; it is possible only as the result of a conjunction of favoring circumstances that must be comparatively very rare. And yet many such instances are on record. As early as 1825, Ami Boul, from the loëss of the Lahr region in the Breisgau, discovered a human skeleton, and two years afterward a human skull,[2] with bones of the mammoth and other diluvial animals, from the loëss at Eguisheim, near Colmar. The study of the deposit in which the latter of these two discoveries was made, with the relative positions of the remains themselves, and the chemical analyses of them by Dr. Scheurer-Kestner, of Thann, leave no room for doubt that the man and the animals were synchronous, both in life and in the deposition of their remains.

And many localities yield human bones and implements mingled with remains of diluvial animals, especially of the mammoth, the rhinoceros of the species previously described, and the cave-bear. Especially rich in these combined relics are caves of Lenu and Sombrive, in the department of Ariége, France, and of Engihoul and Engis, near Lüttich (Liège), Belgium. The contents of the latter two

[1] *Matériaux pour servir à l'histoire de l'homme.*

[2] Elaborately described by Dr. Fandel, of Colmar.

caves were described by Schmerling, in his admirable but neglected works, some thirty-five years ago.

The Neanderthal cave[1] has become celebrated. An entire human skeleton of good size and proportions, save its ape-like, low-browed skull, was discovered here in 1856,[2] a full account of which was given by Dr. Fuhlrott. This discovery, since become the occasion of so much discussion, indicates quite clearly the existence in that remote period of a race of men of marked characteristics, and in some peculiarities closely resembling certain now-living Australian tribes. The skull is not nearly of so high a type as that from the Engis cave just mentioned.

Of exceptional interest, also, is the burial-place at Aurignac, in the department of Haute-Garonne, in Southern France. It was accidentally discovered in 1852, but first scientifically described in 1861, by Lartet. There, in a cave closed by a vertical slab of stone, which was itself hidden by accumulated stone fragments dropped from the cliff above, were found no less than seventeen human skeletons, mingled with bones of the cave-bear, cave-lion, mammoth, rhinoceros, giant-elk, and other now-extinct diluvial animals, weapons of wrought-flint and implements of bone, stag's-horn, and ivory—articles probably buried with the dead for use in the life beyond the grave; in the belief of which Sir Charles Lyell, in his work on the "Antiquity of Man," quotes as pertinent the well-known lines from Schiller's "Nadowessian Death-Song:"

"Here bring the last gifts—and with these
The last lament be said:
Let all that pleased, and yet may please,
Be buried with the dead.

"Beneath his head the hatchet hide
That he so stoutly swung:
And place the bear's fat haunch beside—
The journey hence is long.

"And let the knife new sharpened be,
That, on the battle-day,
Shore with quick strokes—he took but three—
The foeman's scalp away!"[3]

In exact agreement with one of these lines, the thigh-bones of the cave-bear were actually found laid beside some of the skeletons of this cave. Not a trace of pottery was found here. Under the *débris* mentioned as lying just outside of the door of the cave were ashes, charcoal, and bones of the species found inside, all suggestive of the notion that the funeral-feast may have been here celebrated. This heap con-

[1] Near Hochdal, a village on the railroad between Düsseldorf and Elberfeld.—TRANS.
[2] Lyell gives the date 1857.—TRANS.
[3] I have given Sir E. L. Bulwer's version.—TRANS.

tained bones of other yet extant animals also, viz., the aurochs,[1] reindeer, and stag.

Most of the human relics of any sort have been found in the more recent layers of the drift. They have been discovered, however, not only in the older drift, but also, though very rarely, in the underlying Tertiary. For instance, in the upper Pliocene at St.-Prest, near Chartres, were found stone implements and cuttings on bone, in connection with relics of a long-extinct elephant (*Elephas meridionalis*) that is wholly lacking in the drift. During the past two years the evidences of human existence in the Tertiary period—i. e., previous to the age of mammoths of the Diluvial period—have multiplied, and by their multiplication give cumulative confirmation to each other. Even in the lower strata of the Miocene (the middle Tertiary) important discoveries of stone knives and bone-cuttings have been made, as at Thenay, department of Marne-et-Loire, and Billy, department of Allier, France. Prof. J. D. Whitney, the eminent State geologist of California, reports similar discoveries there also. So, then, we may believe that before the last great upheaval of the Alps and Pyrenees, and while the yet luxuriant vegetation of the then (i. e., in the Tertiary period) paradisaic climate yet adorned Central Europe, man inhabited this region.

Such discoveries relegate the beginning of human life to a time the remoteness of which is to be estimated not by years, but by millenniums. It is of course difficult to even approximate to a date so distant, but there is reason to believe it must have been at least 50,000 years ago. Even the Indian, Persian, Assyrian, and Egyptian civilizations, with their languages, literatures, and achitectural monuments, required a long, long time for their development from their rude beginnings, and hence a far longer time for the whole lifetime of that race. For a people remains a long time in its primitive condition, and its first progress is very slow, as the savage and semi-savage races of today prove to us. But the progress of a people well endowed being begun, it advances with giant strides, at a rate increasing in geometrical ratio.

It were vain to draw positive or detailed conclusions as to the grade of culture attained by the man of the Diluvial period from the comparatively few relics of his life as yet found in the drift and caves. These data are yet too few, slight, and disconnected, for that. For instance, while some of the skulls (that from the Neanderthal especially) indicate an ape-like race, of short stature, others are of a type far higher, and scarcely differing from those of European tribes yet living.

A human jaw-bone, of remarkable cast, was lately taken from the Trou de la Nanlette, a cave on the river Lesse, near Dinant, during

[1] Or Lithuanian bison. A few living specimens of this animal are carefully preserved by the Emperor of Russia.—TRANS.

excavations conducted by M. Edouard Dupont, under the auspices of the Belgian Government. The dental structure is a striking mean between the ordinary human type and that of the ape. Other Belgian and French caves have yielded similar remains, while on the other hand the remains of an ape (*Dryopithecus fontani*), with a dental structure strikingly anthropoid, were found in the upper Miocene beds of the Tertiary at Sansans, department of Gers, in Southern France. In the Trou de la Nanlette long bones of animals in many instances were split longitudinally, for the easy extraction of the marrow. They thus become interesting as early traits of human industry and habits. From the remains as yet found we infer the existence in Europe of a race originally rather ape-like, but progressing toward a build and culture in the complete sense human.

And this is in perfect consonance with the general progress of organic life during the long marches of the various geological eras. The present is thus the era of the highest types. We are still told by many, however, that although every thing in Nature—stone, plant, animal—is stamped with tokens of the law and proofs of the fact of gradual development, man, though equally with them a link in the chain of being—man, forsooth, must have come from the hand of his Creator *immediately*, and perfect from the first.

But let us not draw, from facts as yet comparatively few and very scattered, conclusions which the very first new discovery may reverse. And seeing how few are the human remains yet found in these ancient layers, it is not strange that many hesitate to follow those who already extend the principles of the Darwinian hypothesis to man, and find our very own brethren in the anthropoid apes—brethren sprung from a common ancestry, but immeasurably outstripped by us in the long, long course of a development begun in a previous geological era. But those who accept Darwinism as applied to the animal and vegetable kingdoms, implying as that theory does the progress of organic life from low to higher, from simple to more complex forms and functions—these can hardly resist the conclusion that man also, as to his physical part at least, is but a highly-developed member of the animal kingdom. And, so far as they go, the data of geology favor that view.

Although the anthropoid apes resemble man in structure more closely than they resemble their lower congeners, still the lowest men are far superior, in mental character at least, to these highest apes. And we insist that it is a legitimate subject of inquiry whether the wide chasm now separating the highest apes from the lowest men has existed from the beginning, or whether the spiritual powers of the latter have been developed from the rude beginnings of intellectuality in the former.

The indications are that the primeval man of Europe and his nearer descendants were of short stature. The popular notion, that the present generation is physically weaker and smaller than the primitive or ancient, is not only utterly unfounded, but there is abundant

evidence that the reverse is true. Most of us would be amazed if not shocked at a true and life-size portrait of the real Eve, "mother of all living." We often hear, indeed, of giants' bones here and there dug up, but intelligent examination invariably proves them to have belonged to the mammoth or other animal.[1] A singular blunder of the kind shows the real value of such reputed discoveries. Years ago, a skeleton was dug from the calcareous shale at Oeningen, which the veteran *savant* Scheuchzer confidently christened "*Homo diluvii testis*"—the man who saw the flood. Casts of it were made for various museums, and, in full faith in the legitimacy of the name, one Deacon Müller was moved to write some most pious and edifying lines about it. Unfortunately, the first competent study of the skeleton proved it to be that—not of an ancient sinner, but of a large salamander, closely resembling the Giant Salamander of Japan. Yet, to this day, every casually unearthed petrifaction, found no matter where or in what relations, is to many a memorial of the Noachian Deluge. Thus, theories which science has long ago refuted and dismissed from further consideration, are persistently held fast and reaffirmed.

If we are to attain even an approximate notion of the grade of culture reached by what we must provisionally regard as the autochthonic, primitive man of Europe, we must infer it from the yet preserved works of his hands rather than from the lamentably few osseous remains yet found with them. He had various articles of bone and horn, clubs and slings, and knives and spear-heads, some of which were long and slender, some short and round, chipped into shape out of flint and jasper. He had no pottery as yet, and no wrought metals. He split the longer bones of animals used as food, the better to get at the marrow; and this was not only eaten, but probably then, as by many savage races at present, employed as an unguent also. The domestication of animals was evidently not yet begun—even the horse being used neither for draught nor for carrying. That primitive race contented itself with the wild products of the forest, the chase, and the waters, as to food, and for dwellings used caves, generally in cliffs difficult of access and easy of defense, like those on the river Lesse, near Namur.

We are to picture to ourselves, then, a people very like the Esquimaux in circumstances and activities. It lived in our own Europe, but Europe covered to a considerable extent with glaciers, and keeping up a hard and continuous resistance both to wild beasts and the rigors of a climate at once very cold and very damp. The mammoth and rhinoceros, as we have seen, were protected by thick, woolly hair, and fed upon the twigs of the abundant conifers, as fragments yet found in the interstices of the teeth and ribs show. We must not be misled

[1] Our own papers often tell us of bones or skeletons of men who must have been eight or ten feet in height, but in each case a tape-line and a little knowledge of anatomy reduce them to ordinary proportions.—TRANS.

as to the then climate of Europe by thinking of that of the present habitat of the elephant and rhinoceros. Even now the Bengal tiger traverses Asia as far north as latitude 52°, and the lion and tiger are frequently met with when snow and ice are present.

The tools and weapons of the man of this age were simple indeed, but no mean skill was employed in their manufacture and use. Even with our many and marvelous inventions, one of us, cast away upon some uninhabited shore, could hardly manifest more self-helpfulness. And the manner in which the dead were buried—one of the common modes of expressing a race's faith in a future life—shows the possession of some degree of spiritual development.

Such are "the earliest traces of man in Europe," the slight, sparse indications of his existence in the Tertiary or next preceding formation excepted. These traces of man in the Diluvium belong to the period geologically the most recent indeed, yet even it is separated from our own time by a gulf of many thousands of years. The rhinoceros, primitive ox, giant-elk (*Megaceros Hibernicus*), and cave-bear, are prominent among the contemporaries of this primitive man, but the characteristic animal of the time was the mammoth. Hence the name of the first age of Man—the "Age of Mammoths."

We will vainly seek in this earliest man for evidences of that creaturely perfectness which, according to the common view, he must have inherited from his first parents in paradise—the charming paradise of Genesis, of art, and of poetry. For the geologist, the fruits of the truly paradisaic epoch grew in a far remoter past, when Europe was adorned with the palm and cinnamon-tree, and all the exuberant vegetation of the middle Tertiary period, whence our peat-beds are formed; when, instead of man, the ape, or possibly a man not much superior to the ape, stood at the head of God's earthly creatures.

Having answered the question as to man's first traces in Europe, we might now bring our treatise to a close. But, to gain an adequate notion of the antiquity of our race, and of its progress during the successive ages, we proceed to a cursory review of the succeeding eras of prehistoric human existence.

THE ATMOSPHERE IN RELATION TO FOG-SIGNALING.

By JOHN TYNDALL, LL. D., F.R.S.

II.—*Action of Hail and Rain.*

IN the first part of this article it was demonstrated that the optic transparency and acoustic transparency of our atmosphere were by no means necessarily coincident; that on days of marvelous optical clearness the atmosphere may be filled with impervious acoustic clouds,

while days optically turbid may be acoustically clear. We have now to consider, in detail, the influence of various agents which have hitherto been considered potent in reference to the transmission of sound through the atmosphere.

Derham, and after him all other writers, considered that falling rain tended powerfully to obstruct sound. An observation on June 3d has been already referred to as tending to throw doubt on this conclusion. Two other crucial instances will suffice to show its untenability. On the morning of October 8th, at 7.45 A. M., a thunder-storm, accompanied by heavy rain, broke over Dover. But the clouds subsequently cleared away, and the sun shone strongly on the sea. For a time the optical clearness of the atmosphere was extraordinary, but it was acoustically opaque. At 2.30 P. M. a densely black scowl again overspread the heavens to the west-southwest. The distance being 6 miles, and all hushed on board, the horn was heard very feebly, the siren more distinctly, while the howitzer was better than either, though not much superior to the siren.

A squall approached us from the west. In the Alps or elsewhere I have rarely seen the heavens blacker. Vast cumuli floated to the northeast and southeast; vast streamers of rain descended in the west-northwest; huge scrolls of cloud hung in the north; but spaces of blue were to be seen to the north-northeast.

At 7 miles' distance the siren and horn were both feeble, while the guns sent us a very faint report. A dense shower now enveloped the Foreland.

The rain at length reached us; falling heavily all the way between us and the Foreland. But the sound, instead of being deadened, rose perceptibly in power. Hail was now added to the rain, and the shower reached a tropical violence, the hailstones floating thickly on the flooded deck. In the midst of this furious squall both the horns and the siren were distinctly heard; and as the shower lightened, thus lessening the local pattering, the sounds so rose in power that we heard them at a distance of 7½ miles distinctly louder than they had been heard through the rainless atmosphere of 5 miles.'

At 4 P. M. the rain had ceased, and the sun shone clearly through the calm air. At 9 miles' distance the horn was heard feebly, the siren clearly, while the howitzer sent us a loud report. All the sounds were better heard at this distance than they had previously been at 5½ miles; from which, by the law of inverse squares, it follows that the intensity of the sound at 5½ miles' distance must have been augmented at least threefold by the descent of the rain.

On the 23d of October, our steamer had forsaken us for shelter, and I sought to turn the weather to account by making other observations on both sides of the fog-signal station. Mr. Douglas, the chief-engineer of the Trinity House, was good enough to undertake the observations northeast of the Foreland; while Mr. Ayres, the

assistant engineer, walked in the other direction. At 12.50 P. M. the wind blew a gale, and broke into a thunder-storm with violent rain. Inside and outside of the Cornhill Coast-guard Station, a mile from the instruments, in the direction of Dover, Mr. Ayres heard the sound of the siren through the storm; and, after the rain had ceased, all sounds were heard distinctly louder than before. Mr. Douglas had sent a fly before him to Kingsdown, and the driver had been waiting for fifteen minutes before he arrived. During this time no sound had been heard, though forty blasts had been blown in the interval; nor had the coast-guard man on duty, a practised observer, heard any of them throughout the day. During the thunder-storm, and while the rain was actually falling with a violence which Mr. Douglas describes as perfectly torrential, the sounds became audible, and were heard by all.

To rain, in short, I have never been able to trace the slightest deadening influence upon sound. The reputed barrier offered by "thick weather" to the passage of sound was one of the causes which tended to produce hesitation in establishing sound-signals on our coasts. It is to be hoped that the removal of this error may redound to the advantage of coming generations of seafaring men.

ACTION OF SNOW.—Falling snow, according to Derham, is the most serious obstacle of all to the transmission of sound. We did not extend our observations at the South Foreland into snowy weather; but a previous observation of my own bears directly upon this point. On Christmas-night, 1859, I arrived at Chamouni, through snow so deep as to obliterate the road-fences, and to render the labor of reaching the village arduous in the extreme. On the 26th and 27th it fell heavily. On the 27th, during a lull in the storm, I reached the Montanvert, sometimes breast-deep in snow. On the 28th, with great difficulty, two lines of stakes were set out across the glacier, with the view of determining its winter motion. On the 29th, the entry in my journal, written in the morning, is, "Snow, heavy snow; it must have descended through the entire night, the quantity freshly fallen is so great."

Under these circumstances I planted my theodolite beside the Mer de Glace, having waded to my position through snow which, being dry, reached nearly to my breast. Assistants were sent across the glacier with instructions to measure the displacement of a transverse line of stakes planted previously in the snow. A storm drifted up the valley, darkening the air as it approached. It reached us, the snow falling more heavily than I had ever seen it elsewhere. It soon formed a heap on the theodolite, and thickly covered my own clothes. Here, then, was a combination of snow in the air, and of soft, fresh snow on the ground, such as Derham could hardly have enjoyed; still through such an atmosphere I was able to make my instructions

audible quite across the glacier, the distance being half a mile, while the experiment was rendered reciprocal by one of my assistants making his voice audible to me.

The flakes here were so thick that it was only at intervals that I was able to pick up the retreating forms of the men. Still the air through which the flakes fell was continuous. Did the flakes merely yield passively to the sonorous waves, swinging, like the particles of air themselves, to and fro as the sound-waves passed them? Or did the waves bend by diffraction round the flakes, and emerge from them without sensible loss? Experiment will aid us here by showing the astonishing facility with which sound makes its way among obstacles, and passes through tissues, so long as the continuity of the air in their interstices is preserved.

A piece of mill-board or of glass, a plank of wood, or the hand, placed across the open end *t'* of the tunnel *a b c d* (*see* page 689), intercepts the sound of the bell, placed in the padded box *P*, and stills the sensitive flame *k* (described in the last article).

An ordinary cambric pocket-handkerchief, on the other hand, stretched across the tunnel-end produced hardly an appreciable effect upon the sound. Through two layers of the handkerchief the flame was strongly agitated; through four layers it was still agitated; while through six layers, though nearly stilled, it was not entirely so.

Dipping the same handkerchief into water, and stretching a single wetted layer across the tunnel-end, it stilled the flame as effectually as the mill-board or the wood. Hence the conclusion that the sound-waves in the first instance passed through the interstices of the cambric.

Through a single layer of thin silk the sound passed without sensible interruption; through six layers the flame was strongly agitated; while through twelve layers the agitation was quite perceptible.

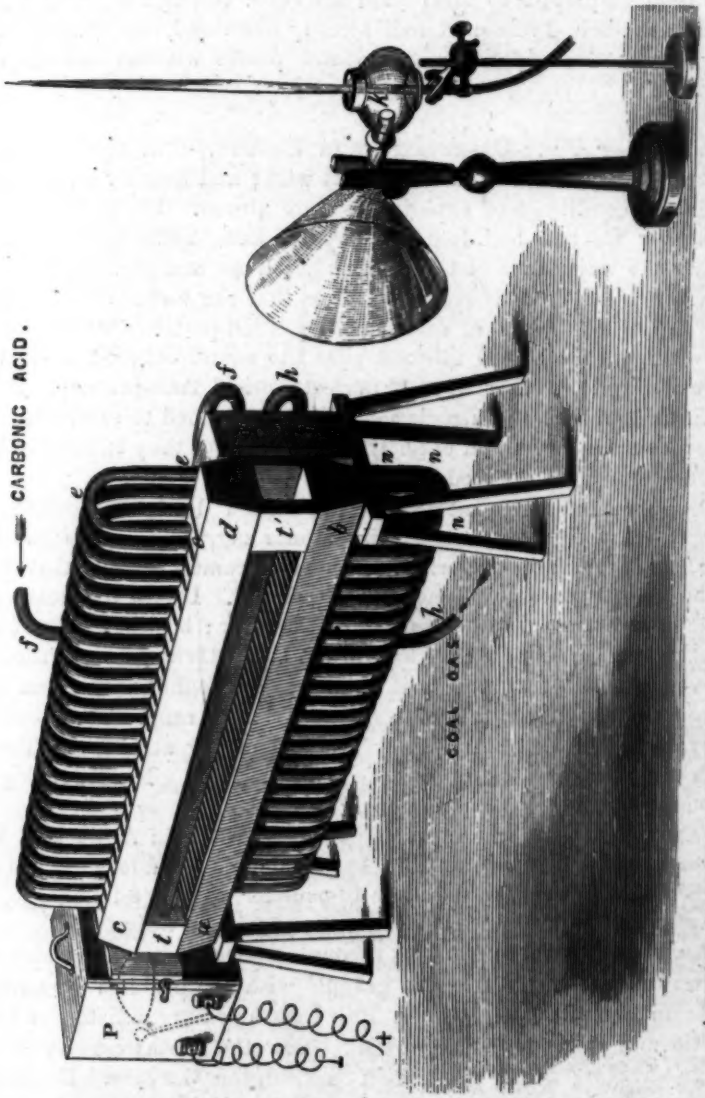
A single layer of this silk, when wetted, stilled the flame.

A layer of soft lint produced but little effect upon the sound; a layer of thick flannel was almost equally ineffectual. Through four layers of flannel the flame was perceptibly agitated. Through a single layer of green baize the sound passed almost as freely as through air; through four layers of the baize the action was still sensible. Through a layer of close hard felt, half an inch thick, the sound-waves passed with sufficient energy to sensibly agitate the flame. I did not witness these effects without astonishment.

A single layer of thin oiled-silk stopped the sound and stilled the flame. A single layer of gold-beater's-skin did the same. A leaf of common note-paper, or even of foreign post, stopped the sound.

The sensitive flame is not absolutely necessary to these experiments. Let a ticking watch be hung six inches from the ear, a cambric handkerchief dropped between it and the ear scarcely sensibly affects the ticking, a sheet of oil-skin or an intensely heated gas column cuts it almost wholly off.

But, though oiled-silk, foreign post, and even gold-beater's-skin can stop the sound, a film sufficiently thin to yield freely to the aërial pulses transmits it. A thick soap-film produces an obvious effect upon the sensitive flame, a very thin one does not. The augmentation



APPARATUS FOR SHOWING THE INFLUENCE OF A NON-HOMOGENEOUS ATMOSPHERE ON THE TRANSMISSION OF SOUND.

of the transmitted sound may be observed simultaneously with the generation and brightening of the colors which indicate the increasing thinness of the film. A very thin collodion-film acts in the same way.

Acquainted with the foregoing facts regarding the passage of

sound through cambric, silk, lint, flannel, baize, and felt, the reader is prepared for the statement that the sound-waves pass without sensible impediment through heavy artificial showers of rain, hail, and snow. Water-drops, seeds, sand, bran, and flocculi of various kinds, have been employed to form such showers: through all of these, as through the actual rain and hail already described, and through the snow on the Mer de Glace, the sound passes without sensible obstruction.

Action of Fog: Observations in London.—But the mariner's greatest enemy, fog, is still to be dealt with; and here for a long time the proper conditions of experiment were absent. Up to the end of November we had had frequent days of haze, sufficiently thick to obscure the white cliffs of the Foreland, but no real fog. Still those cases furnished demonstrative evidence that the notions entertained regarding the reflection of sound by suspended particles were wrong; for on many days of the thickest haze the sound covered twice the range attained on other days of perfect optical transparency. Such instances dissolved the association hitherto assumed to exist between acoustic transparency and optic transparency, but they left the action of dense fogs undetermined.

On December 9th a memorable fog settled down on London. I addressed a telegram to the Trinity House suggesting some gun-observations. With characteristic promptness came the reply that they would be made in the afternoon at Blackwall. I went to Greenwich in the hope of hearing the guns across the river; but the delay of the train by the fog rendered my arrival too late. Over the river the fog was very dense, and through it came various sounds with great distinctness. The signal-bell of an unseen barge rang clearly out at intervals, and I could plainly hear the hammering at Cubitt's Town, half a mile away, on the opposite side of the river. No deadening of the sound by the fog was apparent.

Through this fog and various local noises, Captain Atkins and Mr. Edwards heard the report of a 12-pounder cannonade with a 1-lb. charge distinctly better than the 18-pounder with a 3-lb. charge, an optically clear atmosphere, and all noise absent, on July 3d.

Anxious to turn to the best account a phenomenon for which we had waited so long, I tried to grapple with the problem by experiments on a small scale. On the 10th I stationed my assistant with a whistle and organ-pipe on the walk below the southwest end of the bridge dividing Hyde Park from Kensington Gardens. From the eastern end of the Serpentine I heard distinctly both the whistle and the pipe, which produced 380 waves a second. On changing places with my assistant, I heard for a time the distinct blast of the whistle only. The deeper note of the organ-pipe at length reached me, rising sometimes to great distinctness, and sometimes falling to inaudibility.

The whistle showed the same intermittence as to period, but in an opposite sense; for when the whistle was faint the pipe was strong, and *vice versa*. To obtain the fundamental note of the pipe it had to be blown gently, and on the whole the whistle proved the most efficient in piercing the fog.

An extraordinary amount of sound filled the air during these experiments. The resonant roar of the Bayswater and Knightsbridge roads; the clangor of the great bell of Westminster; the railway-whistles, which were frequently blown, and the fog-signals exploded at the various metropolitan stations, were all heard with extraordinary intensity. This could by no means be reconciled with the statements so categorically made regarding the acoustic impenetrability of a London fog.

On the 11th of December, the fog being denser than before, I heard every blast of the whistle, and occasional blasts of the pipe, over the distance between the bridge and the eastern end of the Serpentine. On joining my assistant at the bridge, the loud concussion of a gun was heard by both of us. A police-inspector affirmed that it came from Woolwich, and that he had heard several shots about 2 P. M. and previously. The fact, if a fact, was of the highest importance; so I immediately telegraphed to Woolwich for information. Prof. Abel kindly furnished me with the following particulars:

"The firing took place at 1.40 P. M. The guns proved were of comparatively small size—64-pounders, with 10-lb. charges of powder.

"The concussion experienced at my house and office, about three-quarters of a mile from the butt, was decidedly more severe than that experienced when the heaviest guns are proved with charges of 110 to 120 lbs. of powder. There was a dense fog here at the time of firing."

These were the reports heard by the police-inspector; on subsequent inquiry it was ascertained that two guns were fired at about 3 P. M. These were the guns heard by myself.

Prof. Abel also communicated to me the following fact:

"Our workman's bell at the arsenal-gate, which is of moderate size and any thing but clear in tone, is pretty distinctly heard by Prof. Bloxam *only* when the wind is *northeast*. During the whole of last week the bell was heard with great distinctness, the wind being *southwesterly* (opposed to the sound). The distance of the bell from Bloxam's house is about three-quarters of a mile as the crow flies."

Assuredly no question of science ever stood so much in need of revision as this of the transmission of sound through the atmosphere. Slowly but surely we mastered the question; and the further we advanced the more plainly it appeared that our reputed knowledge regarding it was erroneous from beginning to end.

On the morning of the 12th the fog attained its maximum density. It was not possible to read at my window, which fronted the open

western sky. At 10.30 I sent an assistant to the bridge, and listened for his whistle and pipe at the eastern end of the Serpentine. The whistle rose to a shrillness far surpassing any thing previously heard, but it sank sometimes almost to inaudibility; proving that, though the air was on the whole highly homogeneous, acoustic clouds still drifted through the fog. A second pipe, which was quite inaudible yesterday, was plainly heard this morning. We were able to discourse across the Serpentine to-day with much greater ease than yesterday.

During our summer observations, I had once or twice been able to fix the position of the Foreland in thick haze by the direction of the sound. To-day my assistant, hidden by the fog, walked up to the Watermen's Boat-House sounding his whistle; and I walked along the opposite side of the Serpentine, clearly appreciating for a time that the line joining us was oblique to the axis of the river. Coming to a point which seemed to be exactly abreast of him, I marked it, and on the following day, when the fog had cleared away, the marked position was found to be perfectly exact. When undisturbed by echoes, the ear, with a little practice, becomes capable of fixing with great precision the direction of a sound.

On reaching the Serpentine this morning, a peal of bells, which then began to ring, seemed so close at hand that it required some reflection to convince me that they were ringing to the north of Hyde Park. The sounds fluctuated wonderfully in power. Prior to the striking of eleven by the great bell of Westminster, a nearer bell struck with loud clangor. The first five strokes of the Westminster bell were afterward heard, one of them being extremely loud; but the last six strokes were inaudible. An assistant was stationed to attend to the twelve-o'clock bells. The clock which had struck so loudly at eleven was unheard at twelve, while of the Westminster bell eight strokes out of twelve were inaudible. To such astonishing changes is the atmosphere liable.

At 7 P.M. the Westminster bell striking seven was not at all heard from the Serpentine, while the nearer bell already alluded to was heard distinctly. The fog had cleared away, and the lamps on the bridge could be seen from the eastern end of the Serpentine burning brightly; but, instead of the sound sharing the improvement of the light, what might be properly called an acoustic fog took the place of its optical predecessor. Several series of the whistle and organ-pipe were sounded in succession; one series only of the whistle-sounds was heard, all the others being quite inaudible. Three series of the organ-pipe were heard, but exceedingly faintly. On reversing the positions and sounding as before, nothing whatever was heard.

At eight o'clock the chimes and hour-bell of the Westminster clock were both very loud. The "acoustic fog" had shifted its position or temporarily melted away.

Extraordinary fluctuations were also observed in the case of the church-bells heard in the morning; in a few seconds they would sink from a loudly-ringing peal into utter silence, from which they would rapidly return to loud-tongued audibility. The intermittent drifting of fog over the sun's disk, by which his light is at times obscured, at times revealed, is the optical analogue of these effects. As regards such changes, the acoustic deportment of the atmosphere is a true transcript of its optical deportment.

At 9 P. M. three strokes only of the Westminster clock were heard; the others were inaudible. The air had relapsed in part into its condition at 7 P. M., when all the strokes were heard.

The quiet of the park this evening, as contrasted with the resonant roar which filled the air on the two preceding days, was very remarkable. The sound, in fact, was stifled in the optically clear but acoustically flocculent atmosphere.

On the 13th the fog being displaced by thin haze, I went again to the Serpentine. The carriage-sounds were damped to an extraordinary degree. The roar of the Knightsbridge and Bayswater roads had subsided, the tread of troops which passed us a little way off was unheard, while at 11 A. M. both the chimes and the hour-bell of the Westminster clock were stifled. Subjectively considered, all was favorable to auditory impressions; but the very cause that damped the local noises extinguished our experimental sounds. The voice across the Serpentine to-day, with my assistant plainly visible in front of me, was distinctly feebler than it had been when each of us was hidden from the other in the densest fog.

Placing the source of sound at the eastern end of the Serpentine, I walked along its edge from the bridge toward the end. The distance between these two points is about 1,000 paces. After five hundred of them had been stepped, the sound was not so distinct as it had been at the bridge on the day of densest fog; hence, by the law of inverse squares, the optical cleansing of the air through the melting away of the fog had so darkened it acoustically, that a sound generated at the eastern end of the Serpentine was lowered to one-fourth of its intensity at a point midway between the end and the bridge.

To these demonstrative observations one or two subsequent ones may be added. On several of the moist and warm days at the beginning of this year I stood at noon beside the railing of St. James's Park, near Buckingham Palace, three-quarters of a mile from the clock-tower, which was clearly visible. Not a single stroke of "Big Ben" was heard. On January 19th, fog and drizzling rain obscured the tower; still from the same position I not only heard the strokes of the great bell, but also the chimes of the quarter-bells.

During the exceedingly dense and "dripping" fog of January 22d, from the same railings, I heard every stroke of the bell. At the end of the Serpentine, when the fog was densest, the Westminster bell

was heard striking loudly eleven. Toward evening this fog began to melt away, and at six o'clock I went to the end of the Serpentine to observe the effect of the optical clearing upon the sound. Not one of the strokes reached me. At nine o'clock and at ten o'clock my assistant was in the same position, and on both occasions he failed to hear a single stroke of the bell. It was a case precisely similar to that of December 13th, when the dissolution of the fog was accompanied by a decided acoustic thickening of the air.[1]

OBSERVATIONS AT THE SOUTH FORELAND.—Satisfactory and indeed conclusive as these results seemed, I desired exceedingly to confirm them by experiments with the instruments actually employed at the South Foreland. On the 10th of February I had the gratification of receiving the following note and inclosure from the deputy-master of Trinity House:

"MY DEAR TYNDALL: The inclosed will show how accurately your views have been verified, and I send them on at once without waiting for the details. I think you will be glad to have them, and as soon as I get the report it shall be sent to you. I made up my mind ten days ago that there would be a chance in the light foggy-disposed weather at home, and therefore sent the Argus off at an hour's notice, and requested the Fog Committee to keep one member on board. On Friday I was so satisfied that the fog would occur that I sent Edwards down to record the observations. . . .

"Very truly yours, FRED. ARROW."

The inclosure referred to was notes from Captain Atkins and Mr. Edwards. Captain Atkins writes thus:

"As arranged, I came down here by the mail express, meeting Mr. Edwards at Cannon Street. We put up at the Dover Castle, and next morning at seven I was awoke by the sounds of the siren. On jumping up I discovered that the long-looked-for fog had arrived, and that the Argus had left her moorings.

"However, had I been on board, the instructions I left with Troughton (the master of the Argus) could not have been better carried out. About noon the fog cleared up and the Argus returned to her moorings, when I learned that they had taken both siren and horn sounds to a distance of 11 miles from the station, where they dropped a buoy. This I know to be correct, as I have this morning recovered the buoy, and the distances both in and out agree with Troughton's statement. I have also been to the Varne light-ship (12¾ miles from the Foreland), and ascertained that during the fog of Saturday forenoon they 'distinctly' heard the sounds."

Mr. Edwards, who was constantly at my side during our summer and autumn observations, and who is thoroughly competent to form a comparative estimate of the strength of the sounds, states that the sounds were "extraordinarily loud," both Captain Atkins and himself

[1] A friend informs me that he has followed a pack of hounds on a clear, calm day without hearing a single yelp from the dogs; while on calm, foggy days from the same distance the musical roar of the pack was loudly audible.

being awoke by them. He does not remember ever before hearing the sounds so loud in Dover; it seemed as though the observers were close to the instruments.

Other days of fog preceded this one, and they were all days of acoustic transparency, the day of densest fog being acoustically the clearest of all.

The results here recorded are of the highest importance, for they bring us face to face with a dense fog and an actual fog-signal, and confirm in the most conclusive manner the previous observations. The fact of Captain Atkins and Mr. Edwards being awakened by the siren proves, beyond all our previous experience, its power during the fog on the 7th of February.

It is exceedingly interesting to compare the transmission of sound on February 7th with its transmission on October 14th. The wind on both days had the same strength and direction. My notes of the observations show the latter to have been throughout a day of extreme optical clearness. The range was 10 miles. During the fog of February 7th, the Argus heard the sound at 11 miles; and it was also heard at the Varne light-vessel, which is 12¾ miles from the Foreland.

It is also worthy of note that through the same fog the sounds were well heard at the South Sand Head light-vessel, which is in the opposite direction from the South Foreland, and actually behind the siren. For this important circumstance is to be borne in mind: on February 7th the siren happened to be pointed, not toward the Argus, but toward Dover. Had the yacht been in the axis of the instrument, it is highly probable that the sound would have been heard all the way across to the coast of France.

It is hardly necessary for me to say a word to guard myself against the misconception that I consider sound to be assisted by the fog itself. The fog-particles have no more influence upon the waves of sound than the suspended particles stirred up over the banks of Newfoundland have upon the waves of the Atlantic. A homogeneous air is the usual associate of fog, and hence the acoustic clearness of foggy weather.

Experiments on Artificial Fogs.—These observations are clinched and finished by being brought within the range of laboratory experiment. Here we shall learn incidentally a lesson as to the caution required from an experimenter.

The smoke from smouldering brown paper was allowed to stream upward into the tunnel *a b c d* (*see* p. 689); the action upon the sound-waves was strong, rendering the short and agitated sensitive flame *k* tall and quiescent. Here the action of the smoke seemed clearly demonstrated.

Air, first passed through ammonia, then through hydrochloric acid,

and thus loaded with thick fumes, was sent into the tunnel; the agitated flame was rendered immediately quiescent, indicating a very decided action on the part of the artificial fog.

Air passed through perchloride of tin and sent into the tunnel produced exceedingly dense fumes. The action of the fog upon the sound-waves was very strong.

The dense smoke of resin, burnt before the open end of the tunnel and blown into it with a pair of bellows, had also the effect of stopping the sound-waves, so as to still the agitated flame.

The result seems clear; and it perfectly harmonizes with the prevalent *a priori* notions as to the action of fog upon sound. But caution is here necessary; for the smoke of the brown paper was *hot;* the flask containing the hydrochloric acid was *hot;* that containing the perchloride of tin was *hot;* while the resin-fumes produced by a red-hot poker were also obviously hot. Were the results, then, due to the fumes or to the differences of temperature? The observations might well have proved a trap to an incautious reasoner.

Instead of the smoke and heated air, the heated air alone from four red-hot pokers was permitted to stream upward into the tunnel; the action on the sound-waves was very decided, though the tunnel was optically empty. The flame of a candle was placed at the tunnel-end, and the hot air just above its tip was blown into the tunnel; the action on the sensitive flame was decided. A similar effect was produced when the air, ascending from a red-hot iron, was blown into the tunnel.

In these latter cases the tunnel remained optically clear, while the same effect as that produced by the resin—smoke and fumes—was observed. Clearly, then, we are not entitled to ascribe, without further investigation, to the artificial fog an effect which may have been due to the air which accompanied it.

Having eliminated the fog and proved the non-homogeneous air effective, our reasoning will be completed by eliminating the heat, and proving the fog ineffective.

Instead of the tunnel *a b c d* (*see* p. 689), a cupboard with glass sides, three feet long, two feet wide, and about five feet high, was filled with fumes of various kinds. Here it was thought the fumes might remain long enough for differences of temperature to disappear. Two apertures were made in two opposite panes of glass three feet asunder; in front of one aperture was placed the bell in its padded box and behind the other aperture, and at some distance from it, the sensitive flame.

Phosphorus placed in a cup floating on water was ignited within the closed cupboard. The fumes were so dense that considerably less than the three feet traversed by the sound extinguished totally a bright candle-flame. At first there was a slight action upon the sound; but this rapidly vanished, the flame being affected exactly as if the sound

passed through pure air. The first action was manifestly due to differences of temperature, and disappeared when the temperature was equalized.

The cupboard was next filled with the dense fumes of gunpowder. At first there was a slight action; but this disappeared even more rapidly than in the case of the phosphorus, the sound passing as if no fumes were there. It required less than half a minute to abolish the action in the case of the phosphorus, but a few seconds sufficed in the case of the gunpowder. The fumes were far more than sufficient to quench the candle-flame.

The dense smoke of resin, when the temperature had become equable, exerted no action on the sound.

The fumes of gum-mastic were equally ineffectual.

The fumes of the perchloride of tin, though of extraordinary density, exerted no sensible effect upon the sound.

Exceedingly dense fumes of chloride of ammonium next filled the cupboard. A fraction of the length of the three-foot tube sufficed to quench the candle-flame. Soon after the cupboard was filled, the sound passed without the least sensible deterioration. An aperture at the top of the cupboard was opened; but, though a dense smoke-column ascended through it, many minutes elapsed before the candle-flame could be seen through the attenuated fog.

Steam from a copper boiler was so copiously admitted into the cupboard as to fill it with a dense cloud. No real cloud was ever so dense; still the sound passed through it without the least sensible diminution. This being the case, cloud-echoes are not a likely phenomenon.

In all of these cases, when a couple of Bunsen's burners were ignited within the cupboard containing the fumes, less than a minute's action rendered the air so heterogeneous that the sensitive flame was completely stilled.

These acoustically inactive fogs were subsequently proved competent to cut off the electric light.

Experiment and observation go, therefore, hand-in-hand in demonstrating that fogs have no sensible action upon sound; the notion of their impenetrability which so powerfully retarded the introduction of phonic coast-signals being thus abolished, we have solid ground for the hope that disasters due to fogs and thick weather will, in the future, be materially mitigated.

Action of Wind.—In stormy weather we were frequently forsaken by our steamer, which had to seek shelter in the Downs or Margate Roads, and on such occasions the opportunity was turned to account to determine the effect of the wind. On October 11th, accompanied by Mr. Douglas and Mr. Edwards, I walked along the cliffs to Dover Castle toward the Foreland, the wind blowing strongly

against the sound. On the Dover side, and at about a mile and a half from the Foreland, we first heard the faint but distinct sound of the siren. The horn-sound was inaudible. A gun fired during our halt was also unheard.

As we approached the Foreland we saw the smoke of the gun. Mr. Edwards heard a faint crack, but neither Mr. Douglas nor I heard any thing. The sound of the siren was, at the same time, of piercing intensity. We waited for ten minutes, when another gun was fired. The smoke was at hand, and I thought I heard a faint thud, but could not be certain. My companions heard nothing. On pacing the distance afterward, we were found to be only 550 yards from the gun. We were shaded at the time by a slight eminence from both the siren and the gun, but this could not account for the utter extinction of the gun-sound at so short a distance, and at a time when the siren sent to us a note of great power.

Mr. Ayres, at my request, walked to windward along the cliff, while Mr. Douglas proceeded to St. Margaret's Bay. During their absence I had three guns fired. Mr. Ayres heard only one of them. Favored by the wind, Mr. Douglas, at twice the distance, and far more deeply immersed in the sound-shadow, heard all three reports with the utmost distinctness.

Joining Mr. Douglas, we continued our walk to a distance of three-quarters of a mile beyond St. Margaret's Bay. Here, being dead to leeward, though the wind blew with unabated violence, the sound of the siren was borne to us with extraordinary power.[1] In this position we also heard the gun loudly, and two other loud reports at the proper interval of ten minutes, as we returned to the Foreland.

It is within the mark to say that the gun to-day was heard five times, and might have been heard fifteen times as far to leeward as to windward.

In windy weather the shortness of its sound is a serious drawback to the use of a gun as a signal. In the case of the horn and siren, time is given for the attention to be fixed upon the sound; and a single puff, while cutting out a portion of the blast, does not obliterate it wholly. Such a puff, however, may be fatal to the momentary gun-sound.

On the leeward side of the Foreland, on the 23d, the sounds were heard at least four times as far as on the windward side, while in both directions the siren possessed the greatest penetrative power.

On the 24th the wind shifted to east-southeast, and the sounds, which, when the wind was west-southwest, failed to reach Dover, were now heard in the streets through thick rain. On the 27th the wind was east-northeast. In our writing-room, in the Lord Warden Hotel, in the bedrooms, and on the staircase, the sound of the siren reached

[1] The horn here was temporarily suspended, but doubtless would have been well heard.

us with surprising power, piercing through the whistling and moaning of the wind, which blew through Dover toward Folkestone. The sounds were heard at 6 miles from the Foreland on the Folkestone road, and, had the instruments not then ceased sounding, they might have been heard much farther. At the South Sand Head light-vessel, 3¾ miles on the opposite side, no sound had been heard throughout the day. On the 28th, the wind being north by east, the sounds were heard in the middle of Folkestone, 8 miles off, while in the opposite direction they failed to reach 3¾ miles. On the 29th the limits of range were Eastware Bay on the one side, and Kingsdown on the other; on the 30th the limits were Kingsdown on the one hand, and Folkestone Pier on the other. With a wind having a force of 4 or 5, it was a very common observation to hear the sound in one direction three times as far as in the other.

This well-known effect of the wind is exceedingly difficult to explain. Indeed, the only explanation worthy of the name is one offered by Prof. Stokes, and suggested by some remarkable observations by De la Roche. In vol. i. of the "Annales de Chemie" for 1816, p. 176, Arago introduces De la Roche's memoir in these words: "L'auteur arrive à des conclusions, qui d'abord pourront paraître paradoxales, mais ceux qui savent combien il mettait de soins et d'exactitude dans toutes ses recherches se garderont sans doute d'opposer une opinion populaire à des expériences positives." The strangeness of De la Roche's results consisted in his establishing, by quantitative measurements, not only that sound has a greater range in the direction of the wind than in the opposite direction, but that the range at right angles to the wind is the maximum.

In a short but exceedingly able communication presented to the British Association in 1857, the eminent physicist above-mentioned points out a cause which, *if sufficient*, would account for the results referred to. The lower atmospheric strata are retarded by friction against the earth, and the upper ones by those immediately below them; the velocity of translation, therefore, in the case of wind, increases from the ground upward. This difference of velocity tilts the sound-wave upward in a direction opposed to, and downward in a direction coincident with, the wind. In this latter case the direct wave is reënforced by the wave reflected from the earth. Now, the reënforcement is greatest in the direction in which the direct and reflected waves inclose the smallest angle, and this is at right angles to the direction of the wind. Hence the greater range in this direction. It is not, therefore, according to Prof. Stokes, a stifling of the sound to windward, but a tilting of the sound-wave over the heads of the observers that defeats the propagation in that direction.

This explanation calls for verification, and I wished much to test it by means of a captive balloon rising high enough to catch the deflected wave; but, on communicating with Mr. Coxwell, who has

earned for himself so high a reputation as an aëronaut, and who has always shown himself so willing to promote a scientific object, I learned with regret that the experiment was too dangerous to be carried out.[1]

ATMOSPHERIC SELECTION.—It has been stated that the atmosphere on different days shows preferences to different sounds. This point is worthy of further illustration.

After the violent shower which passed over us on October 18th, the sounds of all the instruments, as already stated, rose in power; but it was noticed that the horn-sound, which was of lower pitch than that of the siren, improved most, at times not only equaling but surpassing the sound of its rival. From this it might be inferred that the atmospheric change produced by the rain favored more especially the transmission of the longer sonorous waves.

But our programme enabled us to go further than mere inference. It had been arranged on the day mentioned, that up to 3.30 P. M. the siren should perform 2,400 revolutions a minute, generating 480 waves a second. As long as this rate continued, the horn, after the shower, had the advantage. The rate of rotation was then changed to 2,000 a minute, or 400 waves a second, when the siren-sound immediately surpassed that of the horn. A clear connection was thus established between aërial reflection and the length of the sonorous waves.

The 10-inch Canadian whistle being capable of adjustment so as to produce sounds of different pitch, on the 10th of October I ran through a series of its sounds. The shrillest appeared to possess great intensity and penetrative power. The belief is common that a note of this character (which affects so powerfully, and even painfully, an observer close at hand) has also the greatest range. Mr. A. Gordon, in his examination before the Committee on Light-houses, in 1854, expressed himself thus: "When you get a shrill sound, high in the scale, that sound is carried much farther than a lower note in the scale." I have heard the same opinion expressed by other scientific men.

On the 14th of October the point was submitted to an experimental test. It had been arranged that up to 11.30 A. M. the Canadian whistle, which had been heard with such piercing intensity on the 10th, should sound its shrill note. At the hour just mentioned we were beside the Varne buoy, 7¼ miles from the Foreland. The siren, as we approached the buoy, was heard through the paddle-noises; the horns were also heard, but more feebly than the siren. We paused at the buoy and listened for the 11.30 gun. Its boom was heard by all. Neither before nor during the pause was the shrill-sounding Canadian whistle once heard. It was now adjusted to produce its ordinary low-pitched note, which was immediately heard. Still farther

[1] Experiments so important as those of De la Roche ought not to be left without verification. I have made arrangements with a view to this object.

out the low boom of the cannon continued audible after all the other sounds had ceased.

But it was only during the early part of the day that this preference for the longer waves was manifested. At 3 P. M. the case was completely altered, for then the high-pitched siren was heard when all the other sounds were inaudible. On many other days we had illustrations of the varying comparative power of the siren and the gun. On the 9th of October, sometimes the one, sometimes the other was predominant. On the morning of the 13th the siren was clearly heard on Shakespeare's Cliff, while two guns, with their puffs perfectly visible, were unheard. On October 16th, two miles from the signal-station, the gun at eleven o'clock was inferior to the siren, but both were heard. At 12.30, the distance being 6 miles, the gun was quite unheard, while the siren continued faintly audible. Later on in the day the experiment was twice repeated. The puff of the gun was in each case seen, but nothing was heard; in the last experiment, when the gun was quenched, the siren sent forth a sound so strong as to maintain itself through the paddle-noises. The day was clearly hostile to the passage of the longer sonorous waves.

October 17th began with a preference for the shorter waves. At 11.30 A. M. the mastery of the siren over the gun was pronounced; at 12.30 the gun slightly surpassed the siren; at 1, 2, and 2.30 P. M. the gun also asserted its mastery. This preference for the longer waves was continued on October 18th. On October 20th the day began in favor of the gun, then both became equal, and finally the siren gained the mastery; but the day had become stormy, and a storm is always unfavorable to the momentary gun-sound. The same remark applies to the experiments of October 21st. At 11 A. M., distance 6½ miles, when the siren made itself heard through the noises of wind, sea, and paddles, the gun was fired; but, though listened for with all attention, no sound was heard. Half an hour later the result was the same. On October 24th five observers saw the flash of the gun at a distance of 5 miles, but heard nothing; all of them at this distance heard the siren distinctly; a second experiment on the same day yielded the same result. On the 27th also the siren was triumphant; and on three several occasions on the 29th its mastery over the gun was very pronounced.

Such experiments yield new conceptions as to the scattering of sound in the atmosphere. No sound here employed is a simple sound; in every case the fundamental note is accompanied by others, and the action of the atmosphere on these different groups of waves has its optical analogue in that scattering of the waves of the luminiferous ether which produces the various shades and colors of the sky.

CONCLUDING REMARKS.—A few additional remarks and suggestions will fitly wind up this paper. It has been proved that in some states

of the weather the howitzer firing a 3-lb. charge commands a larger range than the whistles, trumpets, or siren. This was the case, for example, on the particular day, October 17th, when the ranges of all the sounds reached their maximum.

On many other days, however, the inferiority of the gun to the siren was demonstrated in the clearest manner. The gun-puffs were seen with the utmost distinctness at the Foreland, but no sound was heard, the note of the siren at the same time reaching us with distinct and considerable power.

The disadvantages of the gun are these:

a. The duration of the sound is so short that, unless the observer is prepared beforehand, the sound, through lack of attention rather than through its own powerlessness, is liable to be unheard.

b. Its liability to be quenched by a local sound is so great, that it is sometimes obliterated by a puff of wind taking possession of the ears at the time of its arrival. This point was alluded to by Arago, in his report on the celebrated experiments of 1822. By such a puff a momentary gap is produced in the case of a continuous sound, but not entire extinction.

c. Its liability to be quenched or deflected by an opposing wind, so as to be practically useless at a very short distance to windward, is very remarkable. A case has been cited in which the gun failed to be heard against a violent wind at a distance of 550 yards from the place of firing, the sound of the siren at the same time reaching us with great intensity.

Still, notwithstanding these drawbacks, I think the gun is entitled to rank as a first-class signal. I have had occasion myself to observe its extreme utility at Holyhead and the Kish light-vessel near Kingstown. The commanders of the Holyhead boats, moreover, are unanimous in their commendation of the gun. An important addition in its favor is the fact that in fog the flash or glare often comes to the aid of the sound; on this point the evidence is quite conclusive.

There may be cases in which the combination of the gun with one of the other signals may be desirable. Where it is wished to confer an unmistakable individuality on a fog-signal station, such a combination might with advantage be resorted to.

If the gun be retained as one form of fog-signal (and I should be sorry at present to recommend its total abolition), it ought to be of the most suitable description. Our experiments prove the sound of the gun to be dependent on its shape; but we do not know that we have employed the best shape. This suggests the desirability of constructing a gun with special reference to the production of sound.[1]

An absolutely uniform superiority on all days cannot be conceded to any one of the instruments subjected to examination; still, our observa-

[1] The Elder Brethren have already had plans of a new signal-gun laid before them by the constructors of the War Department.

tions have been so numerous and long-continued as to enable us to come to the sure conclusion that, on the whole, the steam-siren is the most powerful fog-signal which has hitherto been tried in England. It is specially powerful when local noises, such as those of wind, rigging, breaking waves, shore-surf, and the rattle of pebbles, have to be overcome. Its density, quality, pitch, and penetration, render it dominant over such noises after all other signal-sounds have succumbed.

I have not, therefore, hesitated to recommend the introduction of the siren as a coast-signal.

It will be desirable in each case to confer upon the instrument a power of rotation, so as to enable the person in charge of it to point its trumpet against the wind or in any other required direction. This arrangement was made at the South Foreland, and it presents no mechanical difficulty. It is also desirable to mount the siren so as to permit of the depression of its trumpet fifteen or twenty degrees below the horizon.

In selecting the position at which a fog-signal is to be mounted, the possible influence of a sound-shadow, and the possible extinction of the sound by the interference of the direct waves with waves reflected from the shore, must form the subject of the gravest consideration. Preliminary trials may, in most cases, be necessary before fixing on the precise point at which the instrument is to be placed.

The siren, it will be remembered, has been hitherto worked with steam of 70 lbs. pressure or thereabouts; the trumpets have been worked with compressed air; and our experiments have proved that a pressure of 20 lbs. yielded sensibly as loud a sound as higher pressures. The possibility of obtaining a serviceable sound with this low air-pressure may render available the employment of caloric engines with trumpets; if so, the establishment of trumpets on board light-vessels would be greatly facilitated. The signals at present existing on board such vessels are exceedingly defective, and may be immeasurably improved upon. There are, I am told, practical difficulties as to the introduction of steam on board light-ships; otherwise I should be strongly inclined to recommend the introduction among them of the Canadian whistle. The siren would probably be found too large and cumbrous for light-vessels.

The siren, which has been long known to scientific men, is worked with air, and it would be worth while to try how the fog-siren would behave supposing compressed air to be substituted for steam. Compressed air might also be tried with the whistles.

No fog-signal hitherto tried is able to fulfill the condition laid down in a very able letter already referred to, namely, that "*all fog-signals should be distinctly audible for at least 4 miles, under every circumstance.*" Circumstances may exist to prevent the most powerful sound from being heard at half this distance. What may with certainty be affirmed is, that in almost all cases the siren may certainly be relied on

at a distance of 2 miles; in the great majority of cases it may be relied upon at a distance of 3 miles, and in the majority of cases to a distance greater than 3 miles.

Happily the experiments thus far made are perfectly concurrent in indicating that at the particular time when fog-signals are needed, the air, holding the fog in suspension, is in a highly-homogeneous condition; hence it is in the highest degree probable that in the case of fog we may rely upon the signals being effective at far greater distances than those just mentioned.

I am cautious not to inspire the mariner with a confidence which may prove delusive. When he hears a fog-signal he ought, as a general rule (at all events until extended experience justifies the contrary), to assume the source of sound to be not more than 2 or 3 miles distant, and to heave his lead or take other necessary precautions. If he errs at all in his estimate of distance, it ought to be on the side of safety.

With the instruments now at our disposal wisely established along coasts, I venture to think that the saving of property in ten years will be an exceedingly large multiple of the outlay necessary for the establishment of such signals. The saving of life appeals to the higher motives of humanity.

In a report written for the Trinity House on the subject of fog-signals, my excellent predecessor, Prof. Faraday, expresses the opinion that a false promise to the mariner would be worse than no promise at all. Casting our eyes back upon the observations here recorded, we find the sound-range on clear, calm days varying from 2½ miles to 16½ miles. It must be evident that an instruction founded on the latter observation would be fraught with peril in weather corresponding to the former. Not the maximum but the minimum sound-range should be impressed upon the mariner. Want of attention to this point may be followed by disastrous consequences.

This remark is not made without cause. I have before me a "Notice to Mariners," issued by the Board of Trade, regarding a fog-whistle recently mounted at Cape Race, and which is reputed to have a range of 20 miles in calm weather, 30 miles with the wind; and in stormy weather or against the wind 7 to 10 miles. Now, considering the distance reached by sound in our observations, I should be willing to concede the possibility, in a more homogeneous atmosphere than ours, of a sound-range on *some* calm days of 20 miles, and on *some* light, windy days of 30 miles, to a powerful whistle; but I entertain a strong belief that the stating of these distances, or of the distance 7 to 10 miles against a storm, without any qualification, is calculated to inspire the mariner with false confidence. I would venture to affirm that at Cape Race calm days might be found in which the range of the sound will be less than one-fourth of what this notice states it to be.

Such publications ought to be without a trace of exaggeration, and furnish only data on which the mariner may with perfect confidence rely. My object in extending these observations over so long a period was to make evident to all how fallacious it would be, and how mischievous it might be, to draw general conclusions from observations made in weather of great acoustic transparency.

Thus ends, for the present at all events, an inquiry which I trust will prove of some importance, scientific as well as practical. In conducting it I have had to congratulate myself on the unfailing aid and coöperation of the Elder Brethren of the Trinity House. Captain Drew, Captain Close, Captain Were, Captain Atkins, and the deputy-master, have all, from time to time, taken part in the inquiry. To the eminent arctic navigator, Admiral Collinson, who showed throughout unflagging, and, I would add, philosophic interest in the investigation, I am indebted for most important practical aid; he was almost always at my side, comparing opinions with me, placing the steamer in the required positions, and making, with consummate skill and promptness, the necessary sextant observations. I am also deeply sensible of the important services rendered by Mr. Douglas, the able and indefatigable engineer; of Mr. Ayres, the assistant engineer; and of Mr. Price Edwards, the private secretary of the deputy-master of the Trinity House.

The officers and gunners at the South Foreland also merit my best thanks, as also Mr. Holmes and Mr. Laidlaw, who had charge of the trumpets, whistles, and siren.

In the subsequent experimental treatment of the subject I have been most ably aided by my excellent assistant, Mr. John Cottrell.

APOPLEXY.

By J. R. BLACK, M.D.

IF there is any one disease that the diligent brain-worker, a little past middle life, has reason to fear, it is apoplexy. Although statistical evidence is wanting, the experience of the physician confirms the popular belief that more of our distinguished men are carried off by this disease, or by one of its sequels, paralysis, than by any other cause. The influences which tend to produce such a result, and the best means of avoiding them, are the objects we propose briefly to discuss.

A middle-aged physician said one day to the writer: "As I was walking down the street after dinner I felt a shock in the back of my head, as if some one had struck me; I have not felt well since. I fear I shall die, just as all my ancestors have, of paralysis. What shall I

do?" The answer was, "Diminish the tension on the blood-vessels, and there need be no fear of tearing them in a weak place." Now, this expresses in plain terms the exact cause of apoplexy in the great majority of instances; and it is one, too, which every one has it in his power to prevent. A blood-vessel of the brain, from causes which will presently be mentioned, has lost some of its elastic strength; food is abundant, digestion is good; blood is made in abundance, but little is worked off by exercise; the tension on every artery and vein is at a maximum rate; the even, circuitous flow is temporarily impeded at some point, throwing a dangerous pressure on another; the vessel which has lost its elastic strength gives way, blood is poured out, a clot is formed, which, by its pressure on the brain, produces complete unconsciousness. This is the apoplectic stroke. It will be perceived that there are two leading conditions upon which the production of the stroke depends: a lessened strength in the vessel, and an increased tension on it.

There are no vessels carrying blood to and from the various organs of the body which so frequently rupture as those in the brain. The causes that produce this result are the fatty degeneracy of the middle arterial coat of the cerebral vessels, whereby their elastic strength is much impaired, the great irregularity of blood distribution to the contents of the cranium, and the little support which the pulpy substance of the brain gives to the weakened vessels embedded in it.

The forms of degeneracy that are found in the arteries of the brain are the fatty and the calcareous. The microscope has made some startling revelations on this fatty decay. The strong, elastic fibres, that should make up the substance of the middle arterial coat, are, in places here and there, no longer to be seen, their place being occupied by fatty globules, which have very little resisting power to a disturbing force.

The chief causes which produce this structural change are the habitual use of ardent spirits and tobacco. Every one is aware that the leading effects of these agents on the body are such as show that the functions of the nervous system are more affected than any other; and the physician also knows that, when symptoms of disorder arise from their use, they are such as denote that the nervous system is almost alone implicated. Delirium tremens, insomnia, tremulous hands, and nervous headaches, are some of the characteristic effects of the habitual use of stimulants and narcotics.

Ardent spirits also tend to produce an over-fullness of the cerebral vessels, and to affect the functions of the brain in a manner which strangely blends stupidity, brightness, and exhilaration. Effects so unnatural, and so frequently ending in disease, influence injuriously the nutrition of the nervous centres. And to interfere with the nutrition of any part of the body is simply to impair the life and power of its structure. The evidences of this impairment may not be felt im-

mediately. In fact, the evidences of impairment by any bad habit are seldom apparent during the prime of youthful vigor. But the mischief is going on nevertheless, and the organ upon which the weight of infringement falls will be the one that will first manifest signs of disease, and through which death will make its conquest over the body.

Besides this weakening of the vessels upon which the strong impulse of blood from the heart falls at the rate of sixty times a minute, and the very little external support such defective vessels receive from the soft and pulpy brain, there is another source of danger by a break, in the extraordinary ebbs and tides of blood to which the contents of the cranium are subject. During sleep the brain is almost bloodless; its substance seems to shrink into a lifeless mass; but the moment that wakefulness occurs it swells out, gets red, its arteries and veins becoming distended with a great tide of blood. No other part of the body is subject to such droughts and floods in its blood-circulation. This inequality is yet further increased by severe mind-labor. The ardent student is well aware that deep thought heats the head and cools the feet. The brain is then receiving more than an ordinary supply of blood and the feet less.

The first apoplectic stroke, as a rule, is not a severe one. Sometimes the condition of the cerebral circulation is simply that of active congestion; but more commonly a little blood escapes by a tiny vent, the shock to the system slows and enfeebles the action of the heart, the distention of the ruptured vessel is thus lessened, the escape of blood ceases, and Nature, by means of a slight inflammation, heals the part torn, and in due time removes the blood-clot by absorption.

The process by which a weakened blood-vessel is ruptured by internal distention may be illustrated by observing the effect of attempting to force through an old water-hose attached to a fire-engine a large and rapid stream of water. The weakness of the hose is first shown by the escape of tiny jets of water; but by-and-by a larger vent occurs, allowing the water to escape in a flood. Just so it is with the progressive weakening with the blood-vessels in the brain—the escape of blood is at first small; then, under a greater tension than ordinary, a larger rent is made, allowing the blood to escape in hopeless profusion. It was probably these well-known features of apoplectic strokes that led the great Napoleon's medical adviser to make his celebrated reply in reference to this disease, of which the emperor stood in great dread: "Sire, the first attack is a warning, the second a summons, the third a summons to execution."

Those who have a family tendency to apoplexy and are desirous to escape it, will, of course, avoid all the causes above referred to, especially those which tend to destroy the elasticity and strength of the blood-channels in the brain, or, in other words, to weaken the structure and life of those parts. But suppose, as is too often the case, that the

very sort of life has been led and the very habits indulged in which are most likely to produce a weakness and fragility in the coats of the vessels of the brain. What is to be done? *Clearly to diminish and keep the tension on these vessels by the blood at a low rate all the time.* As remarked at the commencement of this article, this is fully in our power by cutting off the supplies. A prudent fire-engineer, when his water-hose are old and weak, would not try to force as much water as he could into them. No; to prevent a rupture he would work them at a low pressure. But men seldom think of carrying out the same simple mechanical principle when there is reason to believe that the vessels of the brain are getting weak and brittle. They eat and drink just as much as they feel inclined to, and sometimes a little more. With a good digestion, nearly all they consume is converted into blood, to the yet further distention of vessels already over-distended. This high-pressure style of living produces high-pressure results. Its effects were painfully illustrated by the death of Charles Dickens. The brain-work he performed was immense; he lived generously, taking his wine as he did his meat, with a liberal hand. He disregarded the signs of structural decay, forcing his reluctant brain to do what it had once done with spontaneous ease, until all at once, under a greater tension than ordinary, a weak vessel gave way, flooding the brain with blood.

Medical writers on this disease all refer to the fact that a stroke of apoplexy quite frequently occurs just after eating a full meal. The experience of physicians also is that violent attacks of vertigo often attend a deranged or inactive condition of the liver. To explain in detail the causes of an unusual pressure of blood on the brain from certain states of the digestive organs would be somewhat tedious. Suffice it to say that it is produced by what may be termed a back-water action of an obstruction to the circulation of the blood, whereby distention occurs in one of the most distensible of the internal organs of the body, the brain. We have already stated that the distribution of blood to the brain is the most irregular in the body; that its blood-vessels are subject to be weakened by improper habits, and that the pulpy cerebral substance gives very little if any support to a weak vessel in it, so that all the conditions favorable to a rupture by a little more distention than ordinary very frequently coexist.

A not uncommon condition of the arteries of the brain, especially at its base, in those far advanced in years, is the displacement in places of the middle coat by lime-particles, which, of course, renders them easily torn. So far as known this condition is incurable, as well as unpreventable. It is one of the changes of structure incident to very old age. The only measure that can be relied upon to prevent a rupture under such conditions is to be cautious about distending them with blood. This is, in fact, the great fundamental principle of prevention when the vessels of the brain are weak from any cause.

To effect this, certain regulations in eating and drinking are far better preventives than any medicine, or even occasional bleedings. The latter method is particularly unsafe. After bleeding from the arm, new blood is often made more rapidly than under other circumstances, and so may become, before a person is well aware of it, very abundant, with a dangerous pressure on the weak vessels. The subject of such a practice is very apt to rely on the abstraction of blood for safety, and take no care otherwise of himself. Besides, he has no accurate means of knowing when the pressure of the blood is becoming dangerously great. The periodical bleeding from piles is a very different matter. They often act as a safety-valve to the high pressure from within, and regulate themselves on mechanical principles. Full-blooded persons, past middle life, and with a predisposition to apoplexy, should never try to remove such a safety-valve.

As soon as old age puts a decided check on the amount of daily exercise, it is time to put a decided check on the amount of food daily consumed. If the supply of new matter is greater than the waste of the old, an accumulation of surplus blood must be the result. The principle is an important one, yet it is little known and less practised. Men well past middle life, who do not exercise half as much as in their younger years, often eat as freely of highly-nutritious food as they ever did. Such a course is very dangerous. The tension on the vascular system must not be increased, but diminished, if the risk of an apoplectic stroke would be avoided.

The kind of food best adapted to keep down superfluous blood is the vegetable. Animal food makes blood with dangerous rapidity, nearly all its substance dissolving for this purpose in the stomach. Laboring-men, however, may eat of animal food in moderation, as the exercise of their muscles wastes their substance largely, requiring a good deal of blood to make up for the wear.

The amount of vegetable food should not be so great as in middle life. The true rule is, not to eat to entire satiety. Even those of younger years and sedentary habits will feel lighter and better in every way by leaving the table a little hungry.

All strong liquors are unsuited to those with an apoplectic tendency. One of their prominent effects, as we have seen, is to cause a degeneration in the coating of the blood-vessels, and another is to move more blood than ordinary upon the brain.

ON THE CORRECTNESS OF PHOTOGRAPHS.[1]

By Dr. HERMANN VOGEL,
PROFESSOR IN THE ROYAL INDUSTRIAL ACADEMY OF BERLIN.

IN the previous chapters we have become acquainted with the development and the theory and practice of photography, and have mentioned cursorily various of its applications. It is our present purpose to give special attention to one point which is of great import in judging of the value of a photograph.

Most persons have a fancy that the application of photography is always uniform, whatever may be the object to be taken, and, therefore, that a photographer who can take a portrait must be able to take equally well a machine, a landscape, or an oil-painting. This results from the erroneous notion that the picture makes itself when the photographer opens and shuts the lid. But our readers know already that the picture does not make itself, but that it must be first developed, brought out, fixed, and copied. In all these operations there is no precise measure or rule how long the photographer should expose to the light, develop, fortify, copy, and tone the picture. This depends on his option and judgment; and he is able at pleasure to bring out the picture more or less in detail, according to the time of exposure. Again, he can make it more or less brilliant, according to the degree of strengthening; he can make it more or less dark, according to the mode of imprinting; more or less blue, according as he tones it down. But what is it that directs his judgment to determine if the picture is correct or not? It is Nature, and Nature alone! He must know Nature, and compare it with his picture. Nor is this easy. Nature appears positive to him, but in the picture she appears first negative; and, if he compares the two, he must be able in his mind to convert the picture, that is, to change it and represent it as a positive, which it is afterward to become. More comparing and study is required to do this than is generally supposed.

If two printed proofs are presented to a man who is ignorant of the art of printing, one of the sheets in question being well and the other ill printed, if the defects be not too glaring, this person will not be able to detect any difference between the proofs. Far otherwise is it with the practised eye of the printer, who immediately detects that in one proof the type is too thick, or thin, or leaded, or that the letters are faint, or blotched, or uneven. In like manner, a practised eye is needed to judge a photograph—an eye not only able to detect the finest details of the picture, but also the peculiarities of the original. The unprofessional man often uses the expression, "I have no eye for

[1] Abridged from the "Chemistry of Light and Photography," No. XIV. of the "International Scientific Series."

it"—that is, "I am not accustomed to see such things"—and it is in this manner that we first discover how imperfectly we use this, the most perfect of our senses.

A man born blind, and who receives his sight by an operation, cannot at first distinguish a cube from a ball, or a cat from a dog. He is not accustomed to see such things, and must first exercise his eyes and learn to see.

We, also, though in possession of sound organs, are blind to all things that we are not accustomed to see; and this fact is most apparent in art, as also in photography, so closely related to it.

If photographers principally engaged in taking portraits are not able to produce a good landscape, the reason of this is that they have no eye for landscape—that they consider a picture to be good after too short an exposure, or when imperfectly developed and strengthened, or when inaccurately printed. It proceeds from their not knowing the influence exercised by the position and intensity of the sun on the aërial perspective produced by clouds, without speaking of other points of less importance.

Thus every class of subjects requires a special study, though the manipulation of photography remains in all cases the same; therefore, there are photographers whose proper province is portraits, and others devoted to landscapes, to the reproduction of oil-paintings, etc.

The remark is frequently made by admirers of photography, that this newly-invented art gives a perfectly truthful representation of objects, understanding by the term truthful a perfect agreement with reality. Photography can, in fact, when properly applied, produce truer pictures than all other arts; but it is not absolutely true. And, as it is not so, it is important to become acquainted with the sources of inaccuracy in photography. Many exist. I shall treat here especially of optical errors.

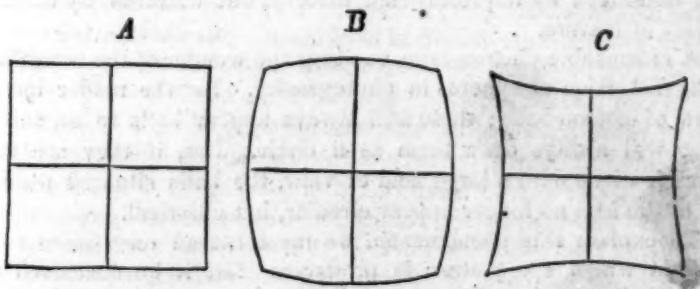


FIG. 1.

The lenses which are employed in photography do not always give absolutely true pictures. Suppose, for example, that a simple lens receives the impression of a square; it often represents it with curvilinear

sides, as in the diagrams *A*, *B*, *C* (Fig. 1), though with a feebler outline. A picture thrown off quite out of drawing by such a lens, in which straight lines turn out as curves, is evidently inaccurate. The inaccuracy may not be felt by many, but it exists. It may perhaps be expected that this defect disappears in the case of what are called correct lenses, but let the attempt be made to obtain a view with these correct lenses of lofty buildings taken from a low position. The lines that ought to be perpendicular commonly converge upward. This is caused by the photographer being obliged to direct his instrument at an acute angle upward, in order to be able to take in a view of the whole building. In doing this, perpendicular lines project themselves, converging upward. To avoid this defect, lenses have been made with a very large field of view. These are called panto-scopes. But these reproduce distant objects apparently on a very

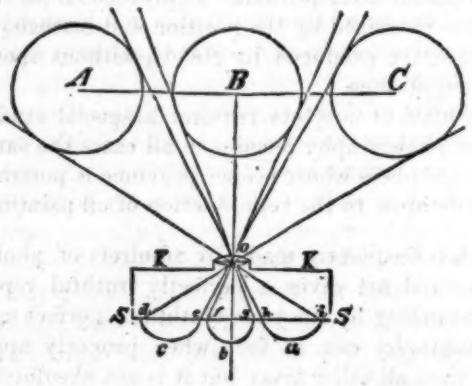


Fig. 2.

small scale, and objects near at hand on a very large scale—peculiarities unnoticed by unprofessional persons, but detected by close observers of Nature.

A remarkable phenomenon, exciting the wonder of the uninitiated, is the distortion of spheres in photography. Let the reader imagine a row of cannon-balls; these will always appear balls to us, and the artist will always draw them as a circle. But, if they are taken through a lens with a large field of view, the balls situated near the rim of the lens no longer appear circular, but elliptical.

To explain this phenomenon, we must attend once more to the mode in which the picture is produced. Let it be conceived that there are three balls, *A B C*, in front of a camera, *K*, with the lens *o* (Fig. 2). Each ball projects a cone of rays on the optical centre of the lens. This is continued within the camera, and cuts the surface of the picture, if its axis falls obliquely upon it, in the form of an ellipse, such as *A C*. Only, if the axis of the cone of rays is perpen-

dicular to the surface of the picture *S S*, as at *B*, the picture appears a circle. I admit that this defect only occurs when the field of view of the lens is very large, and the balls are situated very near its rim.

A photographer brought to the author the picture of a castle having a row of statues in front of it, which he had taken with a lens having a large field of view. Singularly, the heads of the statues toward the margin became continually broader, and similarly their bodies; and the slim Apollo-Belvedere, who unfortunately stood on the very edge of the margin, had such full-blown cheeks and so protuberant a paunch that he looked like Dr. Luther.

But, quite independently of these considerations, there is another point that must materially affect the accuracy of photographic representation. Photography generally gives the light parts too light, and exaggerates the dark shadows. This is a fundamental error which is associated with their very nature, and which it is very difficult to avoid. It is seen in the most evident manner in taking objects lighted by a brilliant sun; for example, a statue. If the exposure is short, a detailed picture is obtained of the light side, but the shady side is a black daub or blotch. If the exposure is long, the shady side is full of detail, but the light side exposed too much, and so thickly covered that the details are wanting in it. Hence photographers are often driven to subterfuges if they wish to obtain a correct picture; they are obliged to mitigate the contrasts—to make the light more toned down, and the shades lighter than painters are wont to make them. The latter often exclaim when they see the photographic exposure of a model, and wonder if the picture will be correct. And no doubt, in the case of landscapes and architecture, the results are not always satisfactory.

The author once took a photograph of the interior of a laboratory. It presented the appearance of an ordinary vaulted hall. All was quite excellent. The tables, stones, retorts, lamps, etc., were all seen, only the vaulted ceiling was quite dark. New attempts were made, with exposures of twenty, thirty, or forty minutes. At length a trace of the vault appeared; but now the objects in the vicinity of the window were suffering from too much exposure; that is, they had become as white as if they had been snowed over. This circumstance of photography exaggerating the dark parts appears again in very simple matters, such as the reproduction of copper-plates. A photographer once reproduced a painting of Kaulbach's "Battle of the Huns." He produced a charming photograph, but the city in the background appeared too thick and black, and not sufficiently toned off. The customer refused the photograph and demanded another. The photographer made another attempt, giving a longer exposure, and now the distance appeared softened down; but, unfortunately, the objects close at hand, which had to appear black and clear, turned out gray. In the end, the photographer escaped from the difficulty by negative

retouche. These are quite ordinary examples to show how difficult it is to reproduce an object correctly.

But we come now to the worst point, that of color. Photography gives the cold colors—blue, violet, and green—too light, and the warm colors too dark. Take as an instance the photographs on sale of "Sunset on the Ganges," by Hildebrandt. It represents a red glowing sun, with clouds of chrome-yellow on an ultramarine sky. But what becomes of all this in the photograph? A black round disk between black thunder-clouds. It looks like an eclipse at Aden. The difficulty of representing Nature is still more patent when the photographer attempts to grapple with higher artistic questions. Let us take an example. There exists a pretty *genre* picture called "A Mother's Love." A mother sits reading in an arm-chair; her little darling embraces her suddenly from behind, and, delightfully surprised, she drops her hand with the book, turns to look at her little pet, and offers her cheek to the little boy to kiss.

A photographer was inspired with the idea of producing a similar picture with the help of a living model. He found a comely maiden, who agreed to personate the mother, and a good-looking boy was also found. An arm-chair for the mother, a chair, and other suitable furniture, were easily procured. The next point was the grouping. The pseudo-mother was very accommodating to the requirements of the photographer, and even assumed a look which, for want of a better, might pass as the expression of a mother's love. But the boy was not of the same mind. He was by no means attracted by the pseudo-mother—he protested against coming near her, and a good cuff was needed to make him take up the requisite position. Time was thus lost. The mother began to feel uncomfortable in the irksome position, straining her neck. The photograph was taken at last, and turned out sharp and without spot or blemish. The models were dismissed, to their great satisfaction. What was the result? The boy was embracing his mother with a face bearing evidence of the cuff he had received, and with a look as if he would have liked to murder her; and she regards him with an expression that seems to say, "Charles, you are very unmannerly," and appears greatly annoyed that her pleasant reading has been interrupted. Can it be said that a picture of this kind correctly expresses the intention of the artist? Does the picture thus produced correspond accurately to the legend, "A Mother's Love?" The untruthfulness of such a picture will be evident to every one.

Thousands of pictures of this class are offered for sale. About ten years ago errors of this kind were committed by the thousand in stereoscopic views, and if they meet with approval this must be referred exclusively to the bad taste of the public. But it may be said in this case it is not the photographer who is guilty, but the unwilling models.

Nevertheless, it is this very circumstance that throws such immense difficulties in the way of taking good photographic portraits. Many persons by no means wish that their characters should be correctly given. The rascal wishes to appear an honorable man in his picture; tottering old men desire to appear young, foppish, and lively; the maid-servant plays the fine lady in the *atelier;* the tradesman's daughter would be a court lady, the street-sweeper a gentleman. Thus the picture serves them only as a means of flattering their personal vanity; and, in order that these people may appear very noble and distinguished, they put on a Sunday's dress, often borrowed and a very bad fit. They practise at home, moreover, before their looking-glass, in the presence of papa, mamma, wife, or lover, impossible attitudes in an artistic point of view. Even cultivated persons are not exempt from these absurdities. Thorwaldsen relates of Byron, who gave him a *séance*, "He sat down opposite to me, but assumed, immediately I commenced, a perfectly different expression. I called his attention to this. 'That is the true expression of my face,' replied Byron. 'Indeed,' I rejoined, and then made his portrait exactly as I wished. All persons declared my bust to be an excellent likeness. But Lord Byron exclaimed, 'The bust does not resemble me; I look much more unhappy.' The fact was, that at that time he wished to look intensely miserable," adds Thorwaldsen. The photographer is even in a worse case. If Byron had come to a photographer, and had presented his face of misery to the camera, what could the photographer have done? He is unfortunately dependent on the model, and many models leave him in the lurch at the critical moment, often not intentionally, but from nervousness or inadvertence. Much depends here on the influence of the photographer, who must know how to control his sitters with courtesy; but many portraits fail without any fault on his part. The author has often witnessed how persons of his acquaintance, at the moment of being taken, assume quite a strange expression without being in the least aware of it.

There are still more characteristic cases of photographic inaccuracy which cannot be attributed to the models. Let us suppose that a photographer, stimulated by the beautiful pictures of Claude, Schirmer, and Hildebrandt, wished to photograph a sunset. He evidently can only expose his plate for a moment to the dazzling bright sun. What sort of a picture is the result? A round white blotch and some shining clouds around it. That is all that appears clearly. All objects in the landscape—trees, houses, and men—have had too short an exposure, and form a black mass. There, where the eye clearly distinguishes road, village, forest, and meadow, it sees in the photograph nothing but a dark patch without any outline. Is such a picture true? Even the most fanatical enthusiast of photography will not dare maintain this.

Such cases, where violent contrasts of light and shade make the production of a correct picture quite impossible, are countless in

number. Let any one examine the majority of the photographs of the white Royal Monument in the Thiergarten at Berlin. The monument is excellently given, but the background of trees is a confused black mass, without details, without shades of tone; the architecture and other features are there, all except the splendid foliage that delights the eye at that spot. Still more numerous are the photographs of rooms, in which the dark corners, quite discernible to the eye, present nothing but pitchy-black night. There are other cases, besides these, of photographic incorrectness.

Suppose we are looking at a mountain landscape. A small village, inclosed on both sides by woody hills, occupies the centre, its houses extending along the declivities and scattered picturesquely among the trees. A ridge of finely-broken mountains in the background, their summits shining in the setting sun, frames in the wonderful picture, whose effect is only injured by one object—a ruinous pig-sty close to the spectator, with a dung-heap beside it. A painter, wishing to paint this scene, would certainly have no scruple about altogether leaving out the pig-sty, or leaving it so indistinct and dark that it would not injure the landscape. But what is the photographer to do? He cannot pull down the offending object. He seeks another position; but there the greater part of the landscape is concealed by trees. He ends by admitting the pig-sty, and what kind of picture is the result? On account of its vicinity, the pig-sty appears of colossal size in the picture. On the other hand, the landscape, which is the principal thing, appears small and inconsiderable. A still more fatal adjunct is found in the dung-heap occupying almost one-fourth of the picture. As the most brightly-lighted part of the photograph, it immediately attracts the eye of the beholder; it diverts his glance from other important points; it acts as a disturbing influence. The photograph obtained does not appear as a picture of the landscape, as it ought to be, but as a view of the pig-sty! The accessory has become the principal point. The picture is untrue. It is untrue, not because the objects it represents were not present in Nature, but because the accessories are presented too glaringly and too large, while the principal parts appear too small, indistinct, and inconsiderable.

This brings us to a weak point in photography, which represents accessories and principal features as equally defined. The plate is indifferent to every thing, while the genuine artist, in reproducing a view of Nature, gives prominence to what is characteristic, and entirely keeps under or softens off accessories. He can dispose and manage it with artistic freedom, and he has a perfect right to do so, because, by his giving prominence to what is characteristic, and dropping what is accessory, he is truer than photography, which gives equal prominence to both, and often more to what is accessory. Reynolds says of the portrait of a lady in which an apple-tree was most carefully painted on the background, "That is the picture of an

apple-tree and not of a lady." Similar remarks might be made on seeing many photographs. It is a cardinal error in their case, that they give a stronger tone to accessories than to essentials. They present a conglomerate of furniture, and it is only after careful inspection that a man is detected sticking among it, whose portrait is to form the picture. In another case a quilted white blouse is seen, and it is only after some time that a girl's head is perceived rising above it. A park is seen in a landscape, with fountains and other adornments, and it is only after some time that a black coat is seen confounded with an equally dark bush.

It may, perhaps, excite surprise that the writer ascribes greater truth to painting than to photography, which is generally regarded as the truest of all methods of producing pictures. It must be self-evident that the remark has only been made in connection with works of the first masters. One of the great services of photography is that it has rendered impossible those daubs of inferior artists formerly offered for sale in every street. But the perfect picture of the photographer is not self-created. He must test, weigh, consider, and remove the difficulties which oppose the production of a true picture. If his picture is to be true, he must take care that the characteristic is made prominent and the accessories subordinate. The non-sensitive plate of iodide of silver cannot do this. It receives the impression of all that it has before it, according to unchangeable laws. The photographer attains this end, on the one hand, by appropriate grouping of the original; on the other, by a proper treatment of the negative. I admit that to do this he must also be able to detect what is characteristic and what accessory in his original.

Therefore, whoever wishes to undertake any photographic production must first become familiar with the object that he wishes to take, that he may know what he has to do. The photographer will not, indeed, be able to control his matter, like the painter, for the disinclination of models and the optico-chemical difficulties often frustrate his best endeavors, and hence there must always be a difference between photography and a work of art. This difference may be briefly summed up by saying that photography gives a more faithful picture of the form, and art a more faithful picture of the character.

MANUFACTURE AND CONVEYANCE OF GUNPOWDER.

By A. HILLIARD ATTERIDGE.

A LITTLE before five o'clock on the morning of the 2d of last October, a train of four barges was being towed by a steamer along the Regent's Canal, in the northwestern district of London. The second of these barges was laden with a miscellaneous

cargo, packed in such a manner, and containing such elements, that the barge was really a very efficient kind of torpedo. In her hold there were about five tons of gunpowder and a quantity of benzoline in kegs. This benzoline may be described as a very volatile species of petroleum. At ordinary temperatures it gives off a highly-inflammable vapor, and this, when mingled with the air in certain proportions, becomes explosive—the explosion running through it at the rate of about two feet per second when it is confined in a tube. In the case of the barge on the Regent's Canal, the cargo was closely covered with a tarpaulin, to protect it from the weather. From the moment, then, that this covering was put on by the bargemen, the vapor given off by the benzoline began to accumulate in the hold, and mingle with the air confined in the spaces between the various packages of the cargo. Thus the hold gradually became filled with a fiery explosive atmosphere, and all that was wanted to produce an explosion was contact with flame. In the little cabin, at the stem of the barge a fire was burning, and there was an aperture in the bulkhead, or partition, which divided the cabin from the hold. Through this the benzoline vapor entered the cabin, and the air in it was soon as vitiated as that under the tarpaulin in the hold. It was ignited by the fire; the explosion, beginning in the cabin, ran forward in a few seconds to the bow, and fired the gunpowder stowed there.

Every one knows what followed. Half London was awakened by the report, which was heard for miles around—to the northward as far as Finchley and Enfield, to the southward as far as Blackheath and Woolwich. Within a radius of from half a mile to a mile from the scene of the explosion houses were wrecked, windows blown in, doors burst open, ceilings shaken down, ornaments and furniture dashed to pieces. A massive bridge over the canal was destroyed, for hundreds of yards its embankment was displaced, and the house which stood nearest to it was so shaken that it had to be pulled down next day. The effect was more like that of a severe shock of an earthquake than any thing else. Fortunately no lives were lost except those of the crew of the barge, but the destruction of valuable property was enormous.

Much alarm has been caused not only in London but throughout the kingdom by this explosion in the heart of the metropolis, and it will have a useful effect in calling attention to the dangerous character of a material so largely employed as gunpowder, and the consequent necessity of carefully regulating its manufacture, storage, and transport, and seeing that these regulations are strictly enforced; for, no matter how perfect our precautions may be in theory, they are worse than useless if we cannot secure their practical efficiency. Without this, their only result must be to lull us into a false security. Gunpowder, and its manufacture and transport, are now subjects in which nearly every one is interested; and we purpose to devote the following

pages to an account of the nature and action of this explosive, its manufacture, and the principles involved in it, and, finally, its transport, and the precautions necessary for our security against explosions like that of last October. We shall describe the process of manufacture in use at the Government mills, as these are probably the most perfect and efficient in the kingdom.

Fifteen miles to the northeast of London, between the sluggish stream of the River Lea and the northern heights of Epping Forest, stands the little village of Waltham, famous for its old abbey, founded by the last Saxon King of England, and destined to be his tomb after the fatal field of Hastings. On both sides of the high-road beyond the village extends a wide tract of flat alluvial ground, traversed by the branches of the Lea, and rich in plantations of willow and alder, with here and there stately rows of poplars. A tall chimney-shaft, the roofs of scattered buildings, and a range of houses near the road, indicate that these well-planted fields are the site of the Royal Gunpowder Factory.

The Waltham Abbey Mills are probably the oldest in Great Britain. They must have been established about the middle of the sixteenth century, for we know that before that time nearly all the powder used in England was imported from the Continent. But in 1561 we hear of John Thomworth, of Waltham, buying, as agent for Queen Elizabeth, saltpetre, sulphur, and staves for making barrels. In the following century the parish register shows entries of deaths resulting from explosions at the mills; and Fuller, who was Rector of Waltham, alludes in one of his works to the dangers of the manufacture, remarking that the mills were blown up five times during the seven years of his residence in the parish. The only wonder is, that explosions were not far more frequent in the old factories, where the elaborate precautions now adopted were utterly unknown. Powder was allowed to accumulate in heaps on the floor, spirits of wine was used instead of water to moisten the ingredients, under the impression that it made better and stronger powder, and the drying process was effected by heating the powder on metal plates over a fire without any means of regulating the temperature. Finally, all the workrooms were close together, and often under a single roof, so that, if the powder in one room exploded, that in the rest would follow, like a boy's train of crackers.

It was in 1787 that Government bought the Waltham Mills from the last private proprietor, Mr. John Walton, supposed by some to have been a descendant of the family of old Izaak. Major (afterward Sir William) Congreve was the first superintendent. Horse and water power only were employed, most of the machinery was of wood, and the incorporating mills were, like mortar-mills at the present time, worked only by horses. Since then great improvements have been introduced into the manufacturing process; the factory has been

widely extended, gun-metal and copper have been largely substituted for wood in the structure of the machines, refining-houses have been erected for purifying the saltpetre and sulphur, and retorts for preparing the charcoal. Machinery has been designed and erected for the preparation of the large cannon-powder introduced of late years, and in the mills iron runners, driven by steam, have taken the place of the stone runners, drawn by old horses. A complete code of rules and precautions has been introduced, and every building protected by a system of lightning-conductors. The factory gives employment to about two hundred men, and can produce twenty-four thousand barrels of gunpowder in the year, and the powder is believed to be at once the best and cheapest made by any existing factory.

Before describing the process of its manufacture at Waltham, it may be as well to note a few facts on its composition and action. Gunpowder may be regarded as a solid, which, by ignition, can be very rapidly converted into a large volume of gas at a high temperature. It is this quality which constitutes it an explosive, for the sudden expansion is what we call explosion, though the name is sometimes given to the loud report which accompanies it, caused by the outrush of the gas generating sound-waves in the air. When the explosion occurs in a confined space, the weakest portion of the confining bodies gives way before it. In quarrying, the rocks are rent, as the gas from the blasting-powder forces them apart. In blowing down walls and gates, the mass of earth heaped on one side to form the "tamping" offers a greater resistance than the wood or stone on the other, and the wall or gate gives way. In firing a cannon, the loose shot offers less resistance than the solid coils of the gun, and it is driven out to a distance proportioned to the force of the charge. If there is any defect impairing the strength of the cannon, or if the shot wedges in the bore, the gun bursts; for nothing we know of can resist the force of the gas. Recent experiments prove that this force, exerted in closed vessels unrelieved by expansion, is equal to a pressure of about forty tons on the square inch.

Of the three materials of which gunpowder consists—sulphur, charcoal, and saltpetre—only the last two are, strictly speaking, essential to it. The gas is actually generated from the charcoal and saltpetre, therefore a mixture of these only will explode. On ignition the charcoal decomposes the saltpetre, its combustion being supported by the oxygen of the latter, in combination with which it forms carbonic-acid gas, and this, mixed with the nitrogen from the saltpetre, is the *gas* which produces the useful effect. But, when gunpowder is thus made with saltpetre and charcoal only, the power developed by the explosion is comparatively trifling, and sulphur has to be added to increase it to such an extent as to make it really efficient. The sulphur acts in two ways to this end. In the first place, it ignites at a lower temperature than either charcoal or saltpetre, and its combustion accelerates

both the decomposition of the saltpetre and the generation of gas, by combining with the potassium of the saltpetre and liberating the oxygen. Then, by heating the carbonic acid and nitrogen, it considerably increases their volume, and consequently their explosive force. The flash, and smoke, and the fouling of the gun, are the result of the decomposition of the saltpetre, and consist of sulphates and carbonates of potassa, resulting from the combination of potassium with the sulphur and carbon. The substances thus formed, swept out into the air, become flame and smoke, or remain in the bore of the gun as fouling, and it is these solid substances that blacken the faces of men engaged in close conflict.

Thus we see that of the materials of gunpowder saltpetre is the most important. Both saltpetre and sulphur arrive in England in a rough state, mixed with various impurities. It is generally the practice in private factories to purchase these materials after they have been refined elsewhere; but at Waltham the refining process is carried on within the works. By this means the materials are obtained of a uniform quality and perfectly pure. The saltpetre comes from various districts of India, chiefly from Bengal and Oude, where it is found mixed with the soil, and as an incrustation on the ground. In India it is boiled, and roughly crystallized by evaporation. When it is required for use in the Gunpowder Factory, it is purified by a process founded on the principle that hot water will receive in solution more of the saltpetre than of the impurities mingled with it. The saltpetre is boiled in water; the resulting solution is then filtered and allowed to cool in large vats, at the bottom of which the pure saltpetre is deposited in fine crystals. It is then washed, dried, and stored in bins, great care being taken that no sand or gritty particles are introduced, as they might cause an explosion when under pressure at subsequent stages of the manufacture, and the same precaution is taken with the sulphur and the charcoal. It is believed that many of the explosions which occur in private factories are caused by foreign substances being present in the materials.

The sulphur is all of the best quality, imported from Sicily. It is purified by a distilling process, which reduces it from its rough state to masses of handsome yellow crystals. It is then pulverized by being ground under iron runners, and sifted in a kind of revolving cylindrical sieve, called a "slope-reel." The sulphur refining-house is, of the whole factory, the least pleasant portion for a visitor, the air being always tainted with the fumes of the sulphur, which are so strong as even to burn and destroy the leaves of the trees near the building. The management of the process is, however, by no means an unhealthy labor. The workman last employed at it died as a pensioner at the ripe old age of eighty, after having worked forty years in the refining-house.

The charcoal is all made on the spot, chiefly from wood imported

from Holland and Germany. The alders and willows in the plantations of the factory furnish but an insignificant supply, probably not enough to make a dozen barrels in the year. They are grown for the most part to form screens around and between the houses, so as to diminish the danger resulting from a possible explosion. The wood employed is of three kinds—alder and willow, which are used for common powder, and black dogwood for fine rifle-powder for the Snider and Martini-Henry. The latter wood is really a kind of buckthorn (*Rhamnus frangula*), of slow growth, and consequently close grain, which forms dense thickets in the forests of Germany, and is also found in the north of England and elsewhere. It is imported in bundles of slender rods about six feet long, and enormous quantities of these bundles may be seen stacked in the fields of the factory. There it is kept for at least three years, though generally it is allowed to lie in store for a much longer time. Some wood has been kept for twenty years, protected from the weather by a roof of thatch, and is still perfectly sound. Strange to say, comparatively little dogwood is used in the powder-factories of Germany, though it is quite certain that it supplies the best charcoal for the purpose.[1] The old plan for charring wood was to burn it in pits, and this is still the practice abroad, but for many years the charcoal at Waltham has been manufactured by sawing the wood into short lengths, and packing it into iron cylinders called "slips," which are placed on a small carriage, and run into a retort very like those used in gas-works. Here the slip is exposed to the flames for a period varying from two and a half to three and a half hours, the gas issuing from the wood in the process being utilized as fuel; and the superintendent of the work knows when the wood is completely charred, by the peculiar color with which the combustion of the gas tinges the fire. As soon as this appears, the slip is withdrawn and cooled. The charcoal when taken out is ground in a machine like a colossal coffee-mill, and then, like the sulphur, sifted in a slope-reel.

The three ingredients are now ready for the regular process of manufacture to be commenced. Up to a certain point (the formation of the "press-cake") the process is the same for whatever purpose the gunpowder is intended, but at that point it divides into two branches, according as it is to be used for heavy guns or smaller weapons. We shall, therefore, first trace the various stages of the manufacture up to the press-house, and then explain the method of making the various kinds of gunpowder, and the objects desired to be obtained by these modifications.

[1] M. Proust's experiments on charcoal, made from various woods, give the following results: 12 grains of charcoal of each wood, mixed with 60 grains of saltpetre and ignited, yielded the following proportions of gas in cubic inches: Dogwood, 80 to 84; willow, 76 to 78; alder, 74 to 75; filbert, 72; fir, 76; elm, 62; oak, 61 to 63. The importance of not overheating the wood is shown by the fact that, when the charcoal consisted of overheated willow, the yield of gas was only from 59 to 66 cubic inches.

The first process is that of simply mixing the ingredients. For this purpose the proper quantities of each are accurately weighed out, allowance being made for a certain amount of moisture in the saltpetre. The proportions vary in different countries, and according to the purpose for which the gunpowder is to be used. For English Government powder of every kind it is—saltpetre 75 parts, sulphur 10, charcoal 15, the sulphur being reduced almost to a minimum, as its chief use is only to ignite the charge and accelerate its action. In France and Prussia the quantity of sulphur is larger, the scale being saltpetre 75 and 12.5 parts each of sulphur and charcoal, while in Chinese powder the amount of sulphur is between 14 and 15. It is remarkable that in all countries the proportion of saltpetre remains about the same.

The ingredients, being weighed for a charge of 50 pounds, are poured into a "churn." This is a revolving drum, placed horizontally, and having within it an axis revolving in a different direction from the drum, and furnished with eight rows of projecting arms, or "fliers." So rapid is the action of this apparatus, that when the charge has been three minutes in the revolving churn the ingredients are thoroughly mixed together. It is then known as a "green charge," and is ready for the incorporating mills, the object of which, as the name indicates, is to incorporate the materials, or to make the mixture so intimate that a new substance is produced, namely gunpowder.

The incorporating-houses at Waltham contain at present thirty-two separate mills. Each mill consists of a pair of runners, coupled together by a strong axle. This axle rests in the socket of an upright shaft, which, passing down through the mill-bed, is connected by bevel-wheels with a revolving horizontal shaft, driven by steam or water-power. The runners are either of black Derbyshire limestone or of iron, and weigh from three and a half to four tons. Iron runners are now generally used, and their size varies from three and a half to seven feet in diameter. The mill-bed, a large circular vat with a flat bottom and sloping sides, is of stone or metal, according to the material of the runners. On this bed 50 pounds of the green charge is spread out and moistened with water, and the mill is then set going. The length of time required for the incorporation of the powder varies according to the use to which it is to be applied. Thus cannon-powder is left under the mills for three hours; while for rifle-powder, which requires a closer incorporation on account of its more rapid action, the time is five hours. The power of a gunpowder-factory is measured by the number of pairs of runners it possesses, for, as the law allows no more than 50 pounds to be placed in any mill at one time, the amount which can be incorporated in a year is easily calculated. A pair of iron runners, driven by steam and working day and night, will incorporate in a year nearly 100,000 pounds of cannon-powder, or about half that quantity of rifle-powder.

This part of the process is more dangerous than any other, and explosions in the incorporating-mills are very frequent. The houses are built of light planking, nailed on a strong framework, so as to diminish the force of the explosion by yielding easily before it. The men are forbidden to remain in them while the mill is in motion, and a very simple arrangement has been devised for preventing an explosion from extending from one mill to another. A shaft runs horizontally through the upper part of the walls of each row of mill-houses. A shutter, balanced by a weight on the other side of the shaft, projects from it over each mill, and this shutter supports one side of a water-tank, the other resting on a pivot. Now, if an explosion takes place in any of the mills, the shutter above it will be blown up, turning the horizontal shaft, and raising all the shutters attached to it; so that the tanks, being left unsupported, turn over, and drench the contents of the mill-beds below.

On leaving the mill, the gunpowder is in the form of a soft cake, which easily breaks up into meal and dust. The old plan for making gunpowder, still followed in some places, was to moisten this mill-cake and force it through fine sieves, so as to break it into grains; but the moisture partly dissolved the saltpetre, and thus, to some extent, destroyed the previous incorporation, and the result was an inferior gunpowder, which, on account of the softness of the grains, often broke up into dust in transport. In the modern process, the mill-cake is first pressed in layers between plates of copper or gun-metal, to increase its hardness and density, and then made into grains of the required form by machinery. As a preparation for the press, the mill-cake is roughly broken down into meal and dust by being passed between grooved gun-metal rollers. It is then ready to be poured into the press-box.

This is a large box of gun-metal, lined with oak, and capable of holding about 800 pounds of powder. The sides are hinged to facilitate unloading, and by means of a small crane it can be swung into or out of the hydraulic press. To be loaded it is turned on one side, a wooden cover placed on the top, and the uppermost side is turned back on its hinges. Then, by means of gun-metal racks, the plates are arranged in the box, with the proper intervals between them to produce a thick cake for cannon-powder, or a thin one if rifle powder is to be made. The powder-meal is then poured in between the plates, the racks withdrawn, the side closed and bolted down. It is then swung by the crane on to the table of the press, and the cover taken off. The press is an ordinary hydraulic one; the table which supports the box is placed on the head of the ram, and as it rises a block of oak fixed overhead enters the box, and presses the powder, the amount of the pressure being measured by the extent to which the block enters the box. The pumps which supply the press with water are fixed in an adjoining room, and worked by a water-wheel; and, in order that the men may know when the pressing is complete without having to

enter the press-room, a kind of catch and trigger is attached to the side of the block, and, as soon as the press-box has been forced up to the required point, the catch is liberated by coming in contact with it, and rings a bell in the pump-room. The pumps are then stopped, the ram falls by its own weight, and the box is unloaded, the gunpowder being taken out in large cakes the size of the metal plates, and as hard as slate. It is in the pressing of the gunpowder that the most serious explosions occur, for, if by any chance the pressure becomes too severe, and the powder explodes in the box, its force is much greater than if it were ignited in the open air. Seven men were killed by an explosion in the press-house at Waltham Abbey in 1843, and by a similar accident on June 16, 1870, five were killed and seven injured.

The question of the density given to gunpowder by pressing and its effects is one which is only now being worked out. Formerly the density of the powder was roughly ascertained by weighing a cubic foot of it, and then its quality was tested by observing to what distance it would fire a shell from a mortar. The primitive methods are now superseded by a testing apparatus, which gives scientifically accurate results. The density is determined by reducing a small quantity of the powder to dust in a mortar, and then placing it in a glass globe provided with stopcocks, one of them connected with an air-pump, and the other with a tube dipping into a vessel of mercury. On exhausting the air, closing the first cock and opening the second, the mercury is forced into the globe, and completely fills it. It is then weighed in a delicate balance, and, its weight when filled with mercury only being known, it is easy to calculate the density of the gunpowder.

Its force is ascertained by observing the initial velocities which it will give to a shot fired from a cannon. These velocities are measured with Bashforth's Chronograph, as explained in a former article in the *Popular Science Review*;[1] and with the Noble Chronoscope, the invention of Captain A. Noble, of the Elswick Works, by means of which we are enabled to ascertain what takes place in the bore of the gun on the explosion of the charge, and what is the velocity of the shot, not only in the whole length of its course within the gun, but also in each portion of that short distance, thus determining the velocity within very small limits both of time and space, and this with the most perfect accuracy.

It is difficult to describe the chronoscope without a diagram, but it is easy to indicate the general principles of its action in a few words, and this will be sufficient for our purpose. A gun having been selected for the experiment, six or eight holes are drilled in one side of it, penetrating to the bore, at intervals along its length from the seat of the shot to the muzzle. Through each of these holes an insulated wire

[1] "On the Striking Velocity of Shot." By W. Royston Pigott, M. D., P. S. R., January, 1871.

enters the gun, its lower extremity being in contact with, but insulated from, a sharp cutting edge, so arranged in the bore of the gun that the passage of the shot would force it down upon the wire and destroy the insulation. Each of the wires is connected with the secondary wire of an induction coil. The recording apparatus consists of a series of disks of polished silver, coated with lamp-black, and made to revolve simultaneously by the action of a falling weight and multiplying wheels at a very high velocity. One of these disks corresponds to each of the wires, the end of which is placed in a small discharger close to its circumference. On firing the charge, the shot cuts the insulation of wire after wire in rapid succession, and as each is cut a current passes, and a spark darts from the discharger to the edge of the revolving disk, striking off a speck of the lamp-black, and leaving the bright silver bare. Now, supposing the velocity of the circumference of the disks to be 1,000 inches per second, and the mark of the electric spark on the second disk to be one inch farther on than that upon the first, this would show that the shot took the $\frac{1}{1000}$ part of a second to pass from the first wire in the gun to the next. Similarly, if the distance between the marks on the first and last disks were five inches, this would indicate that the time the shot took to traverse the whole length of the gun was five-thousandths, or $\frac{1}{200}$, of a second. In reality, the time is even shorter than this. In the 10-inch gun, a 300-pound shot, with a charge of 43 pounds of powder, passes down the bore in something less than the $\frac{1}{210}$ part of a second. So delicate is this apparatus that, by dividing each inch of circumference of the disks into thousandths with the help of the vernier, the $\frac{1}{1000000}$ part of a second would become an appreciable quantity.

It is found, by careful experiment with these appliances and the crusher gauge (by which pressure is estimated by the compression of a copper cylinder placed in the bore of the gun), that the denser the powder is the slower it burns, giving a lower initial velocity to the shot, and exerting a smaller strain on the gun. As an instance of the great differences caused by the smallest variations in density, we give the following results of an experiment with the 10-inch gun, with a charge of 70 pounds:

Density.	Initial Velocity, Feet per Second.	Maximum Pressure, Tons on Square Inch.
1.732	1474	29
1.782	1432	21

Here an increase of .05 in density reduced the velocity by forty-two feet, and the pressure by eight tons. This shows the importance of obtaining a uniform density in the manufacture. For this purpose it is not sufficient to use a uniform pressure in the press-house, as even then the density of different pressings will vary on account of the changing

state of the atmosphere, the different degrees of moisture in the powder-meal, its varying bulk and elasticity, and other minor causes. The only practicable method of securing an approximately uniform density is to test the product of various pressings and then mix them, so as to reduce the whole to the average density required, and this is the constant practice at Waltham.

We have alluded incidentally to the decrease of pressure in the gun as the density of the powder increases. With the immense guns constructed in recent years, it is important to reduce the strain on the metal as far as possible, as this is the only way in which the gun can be safely fired. But it must be remembered that, by seeking to accomplish this by indefinitely increasing the density of the powder, we would at the same time decrease the velocity of the shot, or, in other words, its useful effect. Artillerists have, therefore, had recourse to the expedient of using a powder, each grain of which is a lump of press-cake. The effect of this is to make it burn slower than grain-powder; for these lumps, when ignited at the surface, burn, as it were, in concentric layers, until the whole is consumed; and by this means the explosion, though to all appearance instantaneous, is in reality much more gradual than that which follows the ignition of smaller grains. In other words, the explosion of the charge in a heavy gun is made to be less of the character of a violent blow on the sides of the bore and the base of the shot, and more like a gradual shove given to the shot with a corresponding pressure on the gun.

The first form proposed for cannon-powder for heavy guns was that invented in America by Dr. Doremus, in which the whole charge was made into a solid disk, the size of the bore of the gun. This, however, was found to give very unsatisfactory results. Then the Russian Government adopted a powder compressed into large hexagonal prisms, and in Belgium another powder was made in the form of cylindrical pellets. This was adopted by our Government, and an immense sum was spent on erecting machinery at Waltham for its manufacture, but the pellet-powder has since been superseded by a simpler form, much easier to make, and giving better results; and the pellet machinery has been altered, and, we believe, is now used in the manufacture of gun-cotton.

The pebble-powder now in use consists of cubes of compressed gunpowder, with sides about four-fifths of an inch square. These pebbles are made by passing press-cake of that thickness between two pairs of rollers, armed with sharp-cutting edges. The first pair of rollers, by means of these edges, cuts the cake into several small bars, about four-fifths of an inch square at the ends, and these bars, on passing between the second pair of rollers, are divided into cubes or pebbles. After having been rolled in a hollow cylinder, or reel, to round off the sharp edges and get rid of the dust, the pebbles are carried to the drying-house to be freed from the moisture they contain.

The drying-house is a large room with double doors, and fitted with racks from floor to ceiling. On these racks copper and wooden trays are placed, containing the powder, spread out in thin layers. Steam-pipes are introduced from a boiler in an adjoining building, and thus the air of the room is kept at a temperature of about 135°. The firemen in charge of the drying are forbidden to enter the room for fear of carrying in a spark in their clothes, but they ascertain the temperature by a register thermometer placed inside a small window, and this thermometer also acts as a telltale, by showing if the temperature has at any time been allowed to become too high or too low. So perfect are all the arrangements at Waltham, that no explosion has ever occurred in the drying-house.

The dried pebbles are finished by being placed in a revolving barrel (called a glazing-barrel), with a certain amount of powdered black-lead. On being taken out, every pebble is found to have a perfectly smooth surface coated with black-lead, the effect of which is still further to diminish the rate of burning. The pebbles are then thrown into sieves to separate small fragments; all irregular pieces are picked out by hand, and the remainder is packed in ordinary powder-barrels, which would hold 100 pounds of rifle-powder, but contain 125 pounds of the pebble-powder, on account of its greater density.

The following results of experiments with the 8-inch gun will give the reader an idea of the effects of the different kinds of powder. We need only explain that R. L. G. means the old "Rifle Large Grain" powder, still in use for field-artillery, and draw attention to the fact that the pebble-powder gives at once the highest velocity and the lowest strain:

POWDER.	Charge, Pounds.	Initial Velocity, Feet per Second.	Maximum Pressure, Tons on Square Inch.
R. L. G.....	30	1324	29.8
Russian Prismatic.	32	1366	20.5
Service Pellet....	30	1338	17.4
Pebble.....	35	1374	15.4

Visitors to the laboratory at Waltham can see there a number of experimental varieties of pebble-powder, the largest of which consists of cubes as hard as stone, each side of which is two inches square. A shower of this alone fired from a gun would be quite as effective as grape, and it is possible that 300 pounds of this tremendous powder will form the charge of the new 80-ton gun.

For rifle-powder the meal is pressed into thin cakes; these are broken up into irregular pieces by hand, and carried to the granulating machine. This machine consists of four pairs of toothed cylinders, between which the broken cake is passed. As it falls from them in grains, it is received upon a series of screens of net-work. There are

three of these, the texture of each being closer than that above it, so that large-grain powder is retained on the first, while fine-grain and dust fall through it. The fine-grain remains on the second, and the dust passes on to the third. All the screens are placed in an inclined position, so that the powder runs down them into tubs arranged at the lower end, one of which receives the large, another the fine-grain, and a third the dust.

The powder is then rolled for some hours in the glazing-barrels, to break off all minute irregularities, and give it a smooth surface. Then it is dried, and finally freed from dust in the slope-reel. This done, it is finished by being passed once more through the glazing-barrels, and it is then packed in barrels of 100 pounds each.

Such is the process of the gunpowder manufacture in the Royal Factory at Waltham. We have only briefly indicated the principles of each process, for to go into detail would occupy far greater space than is at our command; but even this sketch will show how at each step science has been called in to aid art in bringing the manufacture to its present high state of perfection. No expense is spared in procuring the best materials, the most efficient machines, and the most accurate tests; yet the cost of manufacture is only about sevenpence per pound. What a contrast to the early days of gunpowder-making, when in France, in 1375, a pound of gunpowder cost a sum equal to ten pounds of our money!

In every department the greatest care is taken to prevent the danger of explosions. The houses are built from 200 to 400 yards apart. Wood, copper, and gun-metal, are the only materials used in the structure of the machines, except where, and that rarely, a bolt of iron is introduced for the sake of strength, and then the metal is encased in leather. The floors are covered with hides secured with copper nails, and these, as well as the wooden platforms round the houses, are kept constantly wet. All loose powder is swept away from the floors, damped, and carried to a magazine, where it is collected and the saltpetre subsequently extracted. No one is allowed to enter a room without putting on a pair of leather "magazine shoes" made without nails, as the iron nails in ordinary boots might lead to an explosion if one trod on the loose powder; and, moreover, one would be certain to bring in grains of grit, which are so dangerous if they become mixed with the powder. The men wear a kind of fire-proof clothing, and in the incorporating-houses leather caps and gloves. Fire-engines are stationed in various parts of the factory, and every man has his post assigned to him in the event of an alarm of fire. To such an extent are these precautions carried that the roofs and eaves of the buildings are searched for birds' nests, and they are pulled down whenever they are found, lest the birds, in building or bringing food to the young, might drop grains of grit or sand on the platforms round the houses. Every building is protected by lightning-conductors, and, as soon as a thun-

der-storm approaches, the men have orders to stop the machinery, leave the houses, close the doors, and cease all work until it has passed over. But the best security for the safety of the factory is that the workmen are a body of steady, industrious, intelligent men, and bear so high a character that a dismissal is a rare event, though it is the penalty of any breach of a necessarily strict code of rules.

The powder manufactured at Waltham is carried down the river Lea to be stored in the great magazines at Purfleet. A useful lesson can be learned from the method of transport. The gunpowder is conveyed in barges specially constructed for the purpose. They are about half the length of an ordinary canal-boat, and are covered with a semicircular roof, with a door at the side, which is kept closed, except when the boat is being actually loaded or unloaded. Every powder-barge is considered a magazine, and the same rules apply to it as to the Government magazines. No fire or light is allowed on board; nothing but powder is to be placed in the hold; and no one is allowed to enter it without wearing the ordinary magazine shoes. In this way it may be said that every chance of an explosion is carefully guarded against. It would be well if the same method of transport were used on canals where (as on the Regent's Canal) gunpowder is being continually carried to and fro. The extra expense of having special barges would not amount to one-hundredth part of the loss caused by an explosion.

We have also to consider the transport of gunpowder by road. It is said that it is a common thing for cart-loads of gunpowder to pass through the crowded streets of London, sometimes several carts closely following each other, and crowding together if there is a block in the traffic. This is unquestionably a very dangerous practice. It would be well if carts laden with any considerable quantity of gunpowder could be prevented from entering the streets of a town; but in many cases this would be impossible. The transport, however, might easily be rendered much safer, by forbidding gunpowder-carts to pass along the streets except during a few hours in the morning, allowing only covered vans to be used, and fixing certain intervals within which no van should approach another. Finally, powder should never be packed in the light kegs used by some manufacturers, which are continually liable to leak, for loose powder is always exposed to ignition by any one of a hundred accidents. There are cases recorded of explosions having taken place through powder leaking from a tumbril, and forming a train upon the ground, which was fired by a spark struck from the shoes of one of the horses drawing it. Good, strong barrels should always be used, and they could of course be returned when empty.

After the Regent's Park explosion there were some fears expressed as to a possible explosion at Purfleet, where about 50,000 barrels of gunpowder are stored in five large magazines. If five tons on board

the canal-barge could do so much damage, what, it was asked, would be the effect of an explosion of the 2,000 tons at Purfleet? Attempts were made to calculate the radius of destruction by Mallet's formula for the effect of bursting shells—the fact being disregarded that the bursting of a shell and the blowing up of a magazine are essentially different affairs. We were told how all East London would suffer from the shock, how several villages in Kent and Essex would be destroyed, and how trains would be thrown off the railway-lines, gasometers wrecked, and a wide district plunged into darkness. We must not forget that an explosion in the open country would have relatively much less force than an explosion in the midst of closely-built streets like those about Regent's Park. An explosion at Purfleet would be very terrible, but probably not half so destructive as one might expect at first sight.[1] Then the Government must keep this large store of powder somewhere; 50,000 barrels could not be manufactured on an emergency, and Purfleet offers advantages in the way of safe and easy transport from Waltham, and shipment to India and the colonies, which mark it as a good site for our chief magazines. The gunpowder might indeed be distributed in numerous magazines, at various points along the lower part of the Thames, but this would really be to increase the chances of an explosion; for, the more numerous is the staff of superintendents and store-keepers, the greater is the danger of carelessness on the part of some among them.

Many a one has said, with the foppish young lord, who so much excited the anger of Hotspur at Holmedon:

> "... That it was great pity, so it was,
> That villainous saltpetre should be digged
> Out of the bowels of the harmless earth,
> Which many a good tall fellow had destroyed."

But, strange as it may seem at first sight, gunpowder and such compounds are as much used in peace as in war. What with practising, salutes, experiments, and reviews, our army, navy, and volunteers, burn every year as much gunpowder as would be required for half a dozen battles and a siege or two. But it is in mining, quarrying, and engineering works, in a word, for industrial purposes generally, that gunpowder is chiefly used; and as strife and peaceful industry cannot exist together, a war, on the whole, tends to lessen rather than increase the consumption of explosive substances. During the great conflict in America the sale and import of gunpowder fell off enormously. It is said that the same thing was noticed in France during the Crimean War; and probably the present war in Spain, by stopping the iron-mines of the north, has diminished the import of blast-

[1] The explosion of a large magazine is really the successive explosion of various portions of its contents, not the detonation of the whole mass. This is why it is fallacious to attempt to estimate the effect of the explosion of 2,000 tons by comparing it with the explosion of a large shell, or of a few barrels on board a barge.

ing-powder to a greater extent than it has accelerated that of powder specially manufactured for military purposes.

The following figures will give an idea of the amount of gunpowder employed in mining operations: It is estimated that in coal-mines about 80 pounds of powder are used for every thousand tons of coal raised. In mines of lead and other minerals, which are found in hard crystalline rocks, about 7,000 pounds of blasting-powder are required for every thousand tons of ore. To quarry a similar quantity of sandstone 170 pounds would be used; while for the harder granite the amount would be 650 pounds.

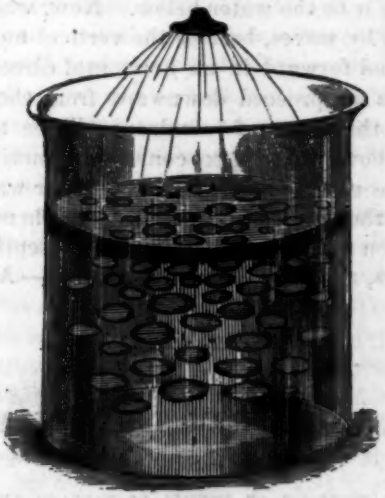
The quantity of gunpowder exported from England has not increased very rapidly of late years. In 1860 it was 11,078,436 pounds, of a declared value of £353,101. In 1865 it had risen to 16,833,723 pounds, valued at £457,078; and in 1870 it was 17,357,668 pounds, valued at £427,229. The increase in weight, with a decrease in value from 1865 to 1870, is due in a great measure to the fact that we export an immense quantity of gunpowder of an inferior quality to non-British ports in Western Africa; and it is in this cheap sort of gunpowder that the chief increase has taken place, while there has been a falling off in the more valuable kinds. Thus, in 1870, no less than 4,637,066 pounds, or more than 25 per cent. of the whole export, went to Western Africa, chiefly to satisfy the warlike propensities of woolly-headed kings; but it will be seen at once what the quality of the powder was, when we add that its declared value was only £83,657, while the comparatively small quantity of 1,173,762 pounds, exported to France, was worth £75,522, or about four times as much in proportion to its weight. Heavy as our loss was at Amoaful, it would have been much more severe if the Ashantees had been provided with something better than this worthless powder. As it was, several of the men in the front line were struck five or six times without being wounded, the bullets having such little force that they fell harmlessly to the ground.—*Popular Science Review.*

RAIN-DROPS ON THE SEA.

By Prof. OSBORNE REYNOLDS, M. A.

THERE appears to be a very general belief among sailors that rain tends to calm the sea, or, as I have often heard it expressed, that rain soon knocks down the sea. Without attaching very much weight to this general impression, my object in this paper is to point out an effect of rain on falling into water which I believe has not been hitherto noticed, and which would certainly tend to destroy any wave-motion there might be in the water. When a drop of rain falls on to

water the splash or rebound is visible enough, as are also the waves which diverge from the point of contact; but the effect caused by the drop under the surface is not apparent, because, the water being all of the same color, there is nothing to show the interchange of place which may be going on. There is, however, a very considerable effect produced. If instead of a drop of rain we let fall a drop of colored water, or, better still, if we color the topmost layer of the water, this effect becomes apparent. We then see that each drop sends down one or more masses of colored water in the form of vortex rings. These rings descend with a gradually diminishing velocity and with increasing size to a distance of several inches, generally as much as eighteen, below the surface. Each drop sends in general more than one ring, but the first ring is much more definite, and descends much quicker than those which follow it. If the surface of the water be not colored, this first ring is hardly apparent, for it appears to contain



DROPS DESCENDING BELOW THE SURFACE.

very little of the water of the drop which causes it. The actual size of these rings depends on the size and speed of the drops. They steadily increase as they descend, and before they stop they have generally attained a diameter of from one to two inches, or even more. The diagram above shows the effect which may be produced in a glass vessel. It is not that the drop merely forces itself down under the surface, but, in descending, carries down with it a mass of water which, when the ring is one inch in diameter, would be an oblate spheroid, having a larger axis of two inches and a lesser of about one and a half inch. For it is well known that the vortex ring is merely the core of the mass of fluid which accompanies it, the shape of which

is much the same as that which would be formed by winding string through and through a curtain-ring until it was full. It is probable that the momentum of these rings corresponds very nearly with that of the drops before impact, so that when rain is falling on to water there is as much motion immediately beneath the surface as above it, only the drops, so to speak, are much larger, and their motion is slower. Besides the splash, therefore, and surface-effect which the drops produce, they cause the water at the surface rapidly to change places with that at some distance below. Such a transposition of water from one place to another must tend to destroy wave-motion. This may be seen as follows: Imagine a layer of water adjacent to the surface, and a few inches thick, to be flowing in any direction over the lower water, which is to be supposed at rest. The effect of a drop would be to knock some of the moving water into that which is at rest, and a corresponding quantity of water would have to rise up into the moving layer, so that the upper layer would lose its motion by communicating it to the water below. Now, when the surface of water is disturbed by waves, besides the vertical motion the particles move backward and forward in an horizontal direction, and this motion diminishes as we proceed downward from the surface. Therefore, in this case, the effect of rain-drops will be the same as in the case considered above, namely, to convey the motion which belongs to the water at the surface down into the lower water, where it has no effect so far as the waves are concerned, and hence the rain would diminish the motion at the surface, which is essential to the continuance of the waves, and thus destroy the waves.—*Nature.*

SCIENCE FROM THE PULPIT.

By JOHN TROWBRIDGE,
ASSISTANT PROFESSOR OF PHYSICS IN HARVARD UNIVERSITY.

ARE ministers fitted to discuss the bearing of modern science upon religion? This question forces itself upon one who is both a member of a church and a lover of science, and deserves to be carefully weighed by those who have the interests of Christianity at heart. An article by the editor of the *Nation*, in the issue of December 24, 1874, takes the very sensible ground that a man of science should have no greater authority in controverted religious questions than the most humble member of a church. His views are not entitled to great consideration simply because he is a student of science. This seems to touch the vital part of the question. The history of the world shows, however, that the assumption of exclusive right to treat religious questions with authority, and the barring out of critical in-

truders, have always come from a class of men who are peculiarly unfitted by education to see the bearing of modern investigation. The Church should be eager to receive the discoveries of investigators of the strange and wonderful works of the Creator, with confidence that all can and must be reconciled with revealed religion. We see very little of this eager, receptive condition among ministers. On the contrary, the occupants of the pulpits immediately assume a fretful condition of indignation. They bristle at the very mention of the doctrine of evolution, of prehistoric man, and the theories of the antiquity of the world.

The address of Prof. Tyndall has been criticised from a hundred pulpits. If carefully read, it will not be found to afford material for the wave of indignation which has swept over the religious world. The address was evidently inspired by an indignant feeling of protest against religious dictation in science, which was tinctured also by a certain want of reverence characteristic of many scientific men. This deficiency in reverence is to be lamented, but the attitude of an investigator is generally one of irreverence. Prof. Tyndall is quick to perceive the scientific questions which are to be fashionable, so to speak, among the general public. He early saw the tide of interest which was setting toward the ice-formations of Switzerland. He led the general public to appreciate the doctrine of the conservation of force by his admirable treatise on "Heat as a Mode of Motion." He is the pioneer in the modern style of popular scientific lectures, which gives to beauty of experimental illustration a lucid yet imaginative diction. No less ready has he been to perceive the coming ferment in religious matters; and he has dashed gallantly into the combat with a certain Celtic fire, leaving perhaps many unguarded points. It may be that he considers that the religious agitation in Germany has nothing to do with the prerogatives of emperor or pope: but that bigoted religion and science are the true antagonists, and, with his customary insight into the scientific tendencies of the age, he is eager to be the first in the field. There is much in the spirit of protest which the Belfast address breathes that appeals to the mind of every scientific man.

Ministers who are only general readers in science can have no conception of the scientific spirit which comes through investigation. There is a cultivated interest which arises only from familiarity with methods, processes, and instruments. A minister lives apart from the seething turmoil and progress of the scientific world; and, if he should attempt to dispute with innovators, he will meet the same fate as any comparative recluse who attempts to dictate to the world from his retirement.

Nothing leads thinking young men of scientific tendencies to neglect church-going more than wrong-headed and illogical deductions from science by their pastors. They hear the doctrines of Darwin

condemned by men who have not carefully read the many treatises for and against evolution, and who have not sound conceptions of the true grounds of the learned authors. The writer once heard a divine vigorously controvert the doctrines of Darwin, and exhaust his resources of invective upon the unfortunate believers in the evolution theories of the present, much to the edification of the regular churchgoers, who, for the most part, had never read the books which were criticised, but had a general idea that Darwinism, socialism, and communism, were equally pernicious to the welfare of society. The occupant of the pulpit, upon seeing that he swept his audience with him, elevated himself to his full height and exclaimed, "If they believe that man descended from an ape, let them take a monkey from the Zoological Gardens, and, by a process of natural selection and cultivation, make a man of him. Surely this is not unreasonable to ask!"

I often hear sermons from men who admire the progress of science, yet who do incalculable damage by drawing wide and unwarrantable inferences and conclusions from scientific facts. These inferences are often made by men who are well read in the scientific literature of the day, but who do not regard the limits of scientific generalizations, and take steps which the scientific hearer would not dream of taking. The hearer, knowing how defective the preacher's judgment is in his inferences from science, naturally doubts the clearness of his pastor's judgment on even purely theological points. The attempt to reconcile science and religion is like an endeavor to measure two constantly-expanding scales by comparison with each other. It does not seem to be recognized that a scientific man can have a religion apart from his science: that it is not necessary for him to apply the exact laws of his particular science to his religious convictions, or to test the logic of his belief by the methods which he has found necessary and invaluable in scientific investigations. Many scientific men who are considered atheists are far from being so. It is compatible for a man to be a logical reasoner in an exact science, and yet to refuse to apply the touchstones, which serve him in his science, to his religion. He recognises that his religious belief is an inherent want of his nature. Strict logicians may laugh at him, and claim that he is inconsistent; he himself feels that his tests fail; he cannot reason; he must receive much on faith. Nothing, therefore, is so disagreeable and demoralizing to the man who is loyal, both to his religion and his science, as to hear the attempts of preachers to reconcile an incomplete knowledge of Nature's laws—for, at the best, we are only on the boundaries of the science of Nature—with the great mystery of revealed religion. It were better that the subject should be left untouched; that the minister should be pronounced not in step with progress, than that he should awaken the spirit of opposition and distrust in the minds of the thinkers on scientific problems.

Such are some of the evils of a superficial exposition of science

from the pulpit. If the young student of theology has had a rigid scientific training, it will prove of great advantage to him in the future. Leading minds in the Church recognize that, if the materialism arising from the spread of scientific ideas, received at second hand and fondled until they have deadened religious faith, is to be combated successfully, it must be attacked by men who are not mere superficial readers, who get up their knowledge of science as they would the history of the Reformation. There is a type of character at the present day which is seen in almost every community. The men constituting it, with the most superficial knowledge of science, have their own views upon the causes of natural phenomena. They believe in animal magnetism—in the connection of electricity with every thing that fails to be explained by any other agent. They speculate upon the constitution of suns and comets. Said one of this class to the writer lately: "Do you believe that the sun is heat? You are wrong if you do. I believe that it is electricity." The minister must deal with this type, with sound knowledge. An omnivorous reader, a village wiseacre in science, may easily have, in these days, a little sect of his own in a community. The minister, therefore, cannot ignore science, if he would reach all hearts. Yet an illogical and incomplete treatment of Nature's laws, and wrong deductions and false applications, will be quickly criticised by men who, however much they like to have hypotheses of their own, are harsh and critical to those of their minister.

Let us see what the training is which is to enable our young divinity students to successfully combat the modern scientific materialism. We shall take the catalogues of four leading divinity schools—the schools at Andover, Harvard University, Yale, and Princeton:

At Andover, the *junior year* is devoted to the study of the Hebrew and Greek Scriptures, systematic theology, homiletics, church history, and elocution; the *middle year* is devoted to systematic theology, the Hebrew and Greek Scriptures, church history, and elocution; the *senior year* is devoted to church history, homiletics, Hebrew and Greek Scriptures, pastoral theology, and elocution.

In addition to the regular course of instruction, special courses of lectures are delivered by eminent clergymen on foreign missions, home missions, and Congregationalism.

At the Harvard Divinity School the course consists of the following:

Hebrew Language; principles of criticism and interpretation; the literature, canon, and exegesis of the Old and New Testaments; biblical archæology and geography; natural religion, and the evidences of revealed religion; the philosophy of religion; systematic theology; philosophical and Christian ethics; the ethnic religions, and the creeds of Christendom; ecclesiastical history, and the history of Christian doctrine; church polity and administration.

We learn, from the prospectus of the Yale Theological School, that "the chief aim of the seminary is to train men to be preachers of the Gospel, and especially such teachers as the present state of the world requires." Its course of study is as follows:

Junior year, encyclopædia and literature of theology, and instruction in Hebrew grammar and philology; exegetical study of the Greek New Testament; mental philosophy, with special reference to the study of theology—also natural theology; the evidences of Christianity, and the inspiration of the Scriptures—also, as incidental to these topics, the various forms of skepticism; *middle year*, systematic theology; general church history; Biblical theology; critical study of the New Testament; American church history; *senior year*, sacred rhetoric and homiletics; pastoral theology; Christian doctrine and on symbolical theology; church polity; lectures in natural theology and moral philosophy; natural philosophy; history; political economy; anatomy and physiology. The undergraduate departments are open to the divinity students, as also are the courses in the Sheffield Scientific School.

The course at Princeton differs in having a department entitled "The Harmony of Science and Revealed Religion," extending through the junior and senior years of the undergraduate department as a required course. "The first year of the course includes the study of natural theology, as connected with the physical sciences which illustrate the being and attributes of the Creator; and of natural religion, as connected with the mental and moral sciences which illustrate the Divine government, future state, and probation." The second part of the course includes a similar defense of revealed religion by the inductive logic, with the study of the miraculous, prophetic, historical, and scientific evidences of Christianity. The third part includes the study of inductive science as connected with revealed religion; the history of their seeming conflicts and alliances; the logic applicable to their relations, and the growing evidences of their harmony as alike involving the promotion of perfect science and the vindication of the Christian religion. The text-books used, in the elementary part of the course, are Paley's "Natural Theology," Butler's "Analogy of Religion and Nature," and Bacon's "Novum Organum;" with frequent lectures upon the topics of which they treat, as well as upon other more recent questions emerging in the different sciences which are in relation with revealed religion.

It will be seen that scarcely any attention is paid to a scientific training, or to methods of scientific thought. The young divinity student who enters any theological school—without a preliminary college education—can know nothing of the great questions upon which he is destined to preach with more or less confidence. The time of study, indeed, may be too short for a scientific course in any divinity school. And it is to be doubted whether general lectures on science, or on

scientific methods of thought, illustrated even with the aid of such books as Jevons's "Principles of Science," can do much to enable the young theologian to sufficiently appreciate the attitude of scientific men. Laboratory work will only enable a man to perceive the true scope and limit of science. This laboratory work cannot be undertaken by the young divinity student unless he takes it during a college course, as it is possible to do at Harvard University. An extended scientific training appears to be an impossibility for a young minister; and the most successful sermons seem to the writer, who is both a member of a church and a lover of science, to be those in which argument and logic are laid aside, and simple faith and enthusiasm take their place. A minister cannot expect to meet a scientific man on his own ground, in regard to the scope and bearing of his studies. By his eloquence in denunciation of scientific radicalism he can only hope to carry with him those who are ignorant, and who cling to old traditions. With his present preliminary education a minister cannot influence deep thinkers by any wealth of argument which he may possess. He can only hope to do this by the great power of touching human sympathies which the Bible gives him; by dwelling on the joys and sorrows of man's strange and brief career, and by picturing that hereafter of purity which, we venture to say, no man, even the most short-sighted scientific materialist, ever despairs of.

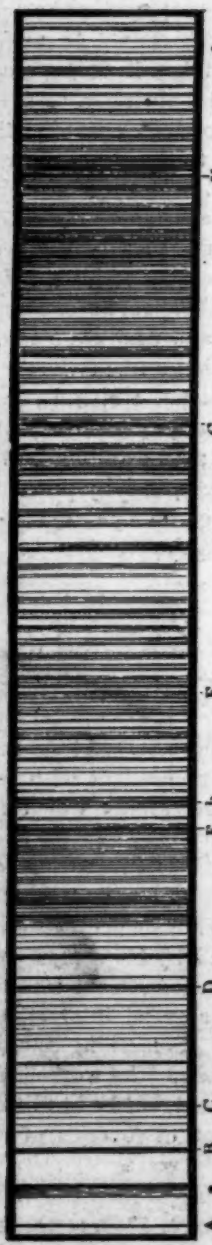
SKETCH OF DR. JOSEPH FRAUNHOFER.[1]

FEW things in the history of science are more interesting than the examples it affords of men devoting themselves with passionate assiduity and untiring persistence to researches which the investigator himself can neither turn to account nor are to be of any ultimate use, and which the public regards as in the last degree frivolous and futile, but the value of which is ultimately and abundantly justified. A man works like a martyr at some obscure and unknown subject, is laughed at and commiserated by his contemporaries, dies, and drops out of memory, until in after-times, in the turns of thought, his results are suddenly invested with a grand interest, and become a passport to their author's immortality. Something like this was the fortune of the subject of the present sketch; he worked in a field which nobody thought of the slightest moment, but he has linked his name forever with one of the most brilliant discoveries of this century.

JOSEPH VON FRAUNHOFER was born in Straubing, Bavaria, March 6, 1787, of humble parents, and was left an orphan in 1799, at the age

[1] Pronounced *Frown'-ho-fer.*

of eleven years, when he was bound out as apprentice to a glass-cutter in Munich, who was very exacting of him in the way and time of his work. The young apprentice, however, without any instructor, found means, in what little time he had to himself, to make up as well as he could the deficiencies of his education, and made great progress in mathematics, besides getting a knowledge of astronomy. From this station he owed his elevation to an accident when nineteen years old. Working himself out unhurt from an old tumble-down house which fell in on him, he became a sort of neighborhood hero, attracting the attention of some gentlemen of wealth and rank who took an interest in the apprentice whom they found trying to cultivate the sciences in such adverse circumstances. They brought him to the notice of and introduced him to the celebrated Reichenbach, who gave him a place as optician in his great establishment for the construction of mathematical and philosophical instruments at Benedictbaiern, near Munich. He found here ample scope for the exercise of his talents, and could now study optics as a science. He soon distinguished himself by his inventive genius and the skill he displayed in the execution of the processes which he was employed upon. The advantages which he enjoyed he turned to account in making many important experiments in light, and constructing superior instruments for astronomical observations. His discoveries greatly increased the reputation of the establishment, of which he finally became the proprietor himself. He made the best crown-glass for achromatic optical instruments, and invented a heliometer, micrometer, and many other scientific contrivances. The celebrated equatorial telescope in the Russian observatory at Dorpat was made by him. In 1819 he moved his great establishment to Munich, and continued his work there till his death, which occurred June 7, 1826, soon after entering upon the fortieth year of his age. He was a member of the University of Erlangen, and of the Royal Academy of Sciences



FRAUNHOFER'S LINES IN THE SOLAR SPECTRUM.

at Munich. Four years before his death, this Academy appointed him keeper of its Museum of Physics. He had the Order of Civil Merit conferred on him by the King of Bavaria, and received the Order of Danebrog from the King of Denmark.

It was as a scientific optician, not only thoroughly familiar with the theory of the subject, but skillful in the use of instruments, and an accurate and painstaking observer, that Fraunhofer entered upon the exploration of a new phenomenon in the solar spectrum.

It is well known that we are indebted to Sir Isaac Newton for the capital experiment of the decomposition of white light into its constituent color-rays. He passed the beam from an opening in a shutter through a glass prism in a darkened room, and got the image of colors in the order of their refrangibility, forming what is familiarly known as the solar spectrum. But this spectrum is not pure. He used the light from a round hole in the shutter, and the ray, when passing through the prism, gave a series of overlapping images of the aperture, by which the colors of the spectrum were somewhat mixed, and, in consequence of this, there was a peculiar class of effects which he did not recognize. His experiment was made in the year 1675, exactly 200 years ago, and for 127 years his method of forming the spectrum was followed, and no step was taken toward the discovery of the phenomena now to be considered. But, in 1802, Dr. Wollaston, an Englishman, examined the spectrum formed by a narrow opening or slit, and found that instead of being so pure as had always been supposed, it was crossed in various places by fine dark lines. The observation attracted no attention at the time, and was not followed up by himself or others.

These dark lines were afterward rediscovered by Fraunhofer, who became so much interested in them that he made them the subject of careful investigation, and his results were so accurate and complete as to have been universally accepted when published in 1814, and the lines from that time have gone under the name of "Fraunhofer's lines." By means of a telescope he observed the spectrum formed by a fine slit, and found that it was crowded with these fine dark lines; that they varied somewhat in thickness, and were distributed in unequal groups throughout the spectral space. He counted 590, from the red to the violet, and made an accurate map of them, as represented in the preceding figure, designating the most important by the letters of the alphabet, large and small, which are still constantly used in the investigations of spectrum analysis.

To the question, What are these dark lines? no clear answer could be given. Science was not as yet prepared to offer an explanation of their cause. Yet Fraunhofer's mind was not idle in regard to this point, and he speculated with great sagacity in the right direction. Optically, or with reference to figure, the dark lines are simply images of the slit. There are of course no such lines in sunlight, but there is

in sunlight that which takes the shape of lines when passed through a narrow opening. The white image from such an opening would of course be a fine white line. If passed through a prism the white line would become a series of colored lines, each point or ray of which would be an image of the slit. If the slit is changed to a cross, then there are crosses in the spectrum. The dark lines, of course, are lines in which light is absent, for darkness is absence of light. There are then certain missing rays in the sunlight that come out in the spectrum as lines of vacancy or breaks in its continuity, and Fraunhofer's lines are all of this kind.

Now, Fraunhofer made the important discovery that the lines of sunlight did not vary when examined at different times. His 590 lines were there, in their exact places, at all times of the day, and at all seasons of the year; the *cause* was therefore probably not in the earth's atmosphere; did not pertain to the earth, and therefore probably existed in the sun. Furthermore, he found that the light from the moon and from Venus gave the same system of dark lines. Fraunhofer saw in Venus-light the double *D* lines; *b* also was seen double, and the relative distance from *D* to *E*, and from *E* to *F*, was the same in the Venus as in the solar spectrum. As this light is reflected from the sun, Fraunhofer was confirmed in the conclusion that these lines are of solar origin.

But he went still further. He made careful and extensive observations of the spectra from the fixed stars, and made the striking discovery that they give groupings of dark lines, which differ from those of the sun and from each other. Some of the stellar lines, however, he showed to be identical with those of the sun. Among the lines of the bright star Procyon he recognized the solar line *D*; and in those of Capella and Betelgueux he found both *D* and *b*. Fraunhofer made also the important observation that the bright-yellow line characteristic of the spectrum of sodium exactly coincided with the double dark solar line *D*. But he could not take a step toward explaining the connection. It was impossible for him to know in what way special rays were cut out or absorbed in the sun and stars, so as to give only darkness, but he got clearly before him the great problem which it is the glory of spectrum analysis to have since resolved.

CORRESPONDENCE.

RETARDATION OF THE EARTH'S ROTATION.

To the Editor of the Popular Science Monthly:

SIR: In the work entitled "Correlation and Conservation of Forces," edited by you, is an article on "Celestial Dynamics," by Dr. J. B. Mayer, in which is considered the subject of the diminution of the velocity of the rotation of the earth, in consequence of the retarding influence of the tidal wave. In the course of this article it is stated (page 297) that "theory and experience agree in the result that the influence of the moon on the rotating earth causes a motion of transition from east to west in both atmosphere and ocean," and that "this motion must continually diminish the rotatory effect of the earth, for want of an opposite and compensating influence."

The result of the retarding force of the waters on the axial motion of the earth is stated, by Dr. Mayer, to be the lengthening of the day $\frac{1}{10}$ of a second in 2,500 years; and, further, that this retarding force will eventually diminish and exhaust the earth's rotatory motion.

The theory of Laplace, that opposite aërial currents are, as to their effects upon the rotation of the globe, as $= 0$, and generally, that there are no forces at work in Nature which do not in Nature find their compensating opposites, is held by Dr. Mayer not to be applicable to the effect of this tidal translation of waters. Nevertheless, he proceeds to demonstrate, in the article on "The Earth's Interior Heat," that the decrease of temperature has been far too great, in the last 2,500 years, to have been without sensible effect in accelerating the velocity of the earth's axial motion. It is there shown that the loss of heat and consequent contraction of the earth's surface, in the time above mentioned, must have had the effect of accelerating the earth's rotatory motion to the extent of counteracting the retarding movement of the tides.

Now, if the results of these forces are equal one to the other, the day remains constant, and the law of Laplace would seem to apply as perfectly in this case as in that of opposing aërial currents.

T. H. S.

CHEYENNE, W. T., *February* 16, 1875.

THE NEST AND EGGS OF THE THISTLE-BIRD.

To the Editor of the Popular Science Monthly:

THE yellow-bird (*Chrysomitris tristis*) is exceedingly abundant throughout New Jersey during eight months of the year, and not at all rare during the winter, when it is seen mostly in loose flocks. For several years I have been perfectly familiar with its manner of nesting, and the appearance of the eggs, etc., and I can give my testimony to the correctness of the statements of Wilson, who says these birds cover the nest "on the outside with pieces of lichen, which they find on the trees and fences." In looking over the first volume of the *American Naturalist*, p. 115, I noticed a statement, made by Dr. T. M. Brewer, that he "never saw one that was ever covered on the outside with lichen;" and, in "North American Birds," vol. i., p. 474, he describes a nest from Wisconsin as *typical*, which, on the exterior, was solely "fine vegetable fibres." Here, in New Jersey, and it was from New Jersey nests (or Pennsylvania) that Wilson took his description, the nests are *invariably* lichen-covered. I believe I am justified in using so positive a term. I know that here, also, two broods are raised. So much for the nests.

I have seen many sets of eggs, probably 200, within ten years, and I know that splotches of yellowish-brown, and occasionally purple, are common on the larger end of the egg; not the rule, perhaps, but *common*, i. e., perhaps thirty per cent. of the eggs laid.

CHARLES C. ABBOTT, M. D.

TRENTON, N. J., *February* 16, 1875.

EDITOR'S TABLE.

THE COMING ECLIPSE.

THERE is little rest for the astronomers. Although their science is the oldest and exactest, and has long since taken its place as one of the most perfected divisions of knowledge, yet there never was a time of greater solicitude in regard to undetermined celestial questions than the present. New problems are presented of transcendent interest, and the progress in the construction of instruments and increasing experience in observation are certain to be rewarded with important extensions of astronomical knowledge.

And there is little rest for the astronomers, not only because of the urgent questions that have recently arisen in their science, but because many of the great phenomena in which they are interested are observable only at critical moments and at rare intervals, and only at a few points upon our planet. The present year will ever be memorable in astronomic annals because of the extensive preparations made to study the transit of Venus; but, while the various parties of observers are returning from the distant stations upon the globe where their observations were made, other expeditions have been fitted out which are traveling again to distant places to observe an eclipse of the sun. This is to take place on the 5th of April; is visible only in the Eastern Hemisphere, and will be mainly observed from stations in the kingdom of Siam. The shadow of total darkness will sweep rapidly along a line of about one hundred miles in breadth, and the time of total obscuration, when all the grand phenomena are displayed, will be but a few seconds more than four minutes. Yet within these fleeting moments many imposing effects are to be accurately noted which will serve as data for resolving the most important questions relating to the constitution of the sun. It was a splendid victory of scientific enterprise when Lockyer and Janssen showed that eclipses could be dispensed with in studying the solar prominences with the spectroscope, and that with their instruments they can at any time sweep round the solar outline, and watch and define those mighty eruptions of gaseous matter which rise to a height of tens and even hundreds of thousands of miles above the photosphere, or light-giving portion of the solar atmosphere; but these observations only heighten the interest of the grand effects which appear when the sun's disk is completely darkened. It is then impressively recognized that this great luminary is very far from being the clear-cut, sharply-defined, luminous globe that it seems to ordinary observation. Its ragged edge is stupendously mountainous, and there moreover stretches away a mighty upper atmosphere, or luminous appendage, called the corona, which can only be examined during the few precious moments of solar darkening.

The corona is therefore now the grand point of attack in a solar eclipse, by telescopic observation, photographic representation, and spectrum analysis; and, with each step of improvement in the construction of instruments, and the facility of their use, we are justified in expecting important accessions to our knowledge of that remarkable phenomenon.

The preparations for observing the April eclipse are suggestive of other considerations which should not be lost sight of. The interests of science are beginning to be recognized throughout the world, and to bring the most diverse nationalities into close relation upon a common platform of sympa-

thetic coöperation. When the different races and nations come into relation in the sphere of politics or religion, antagonisms, discords, jealousies, and hate, are almost inevitably engendered. But, when these are put aside, or kept out of view, and the object to be attained is simply to extend the knowledge of Nature, the better elements of humanity begin to be recognized and asserted. As a striking illustration of this, we have the curious fact that, with reference to the approaching eclipse, it is not the Europeans, but the "King of Siam who has taken the initiative in inviting astronomers to his dominions, and providing for their entertainment while there." On the 9th of last October, his Siamese majesty, through his private secretary, Bhashakarawangse, extended this courtesy to the Royal Astronomical and Royal Societies, and to any astronomers they might accredit to him for the purpose of utilizing the coming opportunity. The English Government sends out an expedition; and an expedition by the French Government goes under the control of M. Janssen. Dr. Hermann Vogel, the eminent Berlin astronomer and photographer, will join the expedition of Janssen at Singapore, and Prof. Tachani will represent the Italian observers.

An intelligent writer in the *Herald*, in the full account which he gives of the preparations for the coming eclipse, thus describes an instrument which has been recently constructed to facilitate observation, and from the use of which much aid is to be expected:

"The siderostat was devised to enable the observer to escape the inconvenience and often the impossibility of changing his position to follow the eye-piece of his telescope, when turned upon the moving sun or star. With the best telescopic mountings and arrangements which have heretofore been employed, the observer is put frequently in the most uncomfortable positions, and his work subjected to those errors irreparable from the nervous handling of his glasses at the exciting and critical moment of the eclipse. The ingenious scientist, Foucault, the perfecter of the siderostat, aimed to give the equatorial the power of making the entire heavens pass before the observer without his having to disturb himself or to displace the instrument. The siderostat, as arranged by him, is, therefore, a telescope fixed horizontally in an invariable position, before which a plane mirror brings successively the various points of the sky. The whole rests on a brass stand, supported by three screws, with two levels and a regulating azimuth movement. The plane mirror is carried by an horizontal axis on the top of two vertical supports, which revolve round a centre, the movement being perfectly effected by small wheels at the foot of the supports. By the employment of the isochronous regulator of Foucault, placed at the foot of the instrument, a motion sensibly equal to the diurnal motion is communicated to the plane mirror, so that the heavenly bodies maintain invariable positions in the field of the horizontal telescope, in front of the apparatus directed toward the mirror. This clock-movement, which has been applied to equatorials, is perfectly regular, and won for its inventor the grand prize in the mechanical arts at the Universal Exhibition of 1867. The apparatus gives perfect steadiness in experiments for measuring the position of spectrum lines and of the displacement of the lines by means of large fixed spectroscopes. Its adaptability has been tested during the recent photographic experiments in connection with the transit of Venus, and with the greatest ease it combines with the observing telescope the apparatus necessary for the work of celestial photography for photometric researches. The complete instrument, telescope and siderostat, placed in the plane of the meridian, may also be regarded as a meridian instrument, so that it is, perhaps, the most powerful weapon of modern astronomy; and, when desired, spectroscopes and photographic apparatus can be attached to the eye-piece of the telescope, of a size even larger than the telescope itself."

THE LITERATURE OF EVOLUTION.

A CORRESPONDENT applied to the editor of the *Nation* asking "for information on books relating to the development or evolution theory, especially for the book 'which is not too partisan or too technical, but gives the facts and reasonings with reference to it on both

sides.'" The editor very properly replied that a work giving the facts and arguments on both sides, fairly and fully, is not to be had; and it may be further observed that the reader who is ignorant of the subject, and specifies exactly the work he wants, will be pretty sure not to find it. The choice must be among such books as are obtainable; and the best way to guide the judgment of the inquirer is, to state impartially what resources there are for getting instruction upon the subject, leaving him to decide as to what will best suit his mental requirements.

The first error into which an uninformed reader, who desires to take up the subject of evolution, is liable to fall, is, that he will probably very much under-estimate the task he proposes to undertake. Assuming that he does not want a mere smattering, but an intelligent view of the doctrine, and the nature and extent of its proofs, he must prepare himself for a very considerable amount of intellectual work. For the "evolution theory," whether we consider it established or not, is the most comprehensive doctrine regarding the order of Nature that has ever yet been presented; and, if it be true at all, it is true as a system of principles underlying various and diverse tracts of phenomena. It is a philosophy of the *origination* of things. To the astronomer it is a theory accounting for the origin of stellar and planetary systems; to the geologist it is a doctrine that explains the history of our globe; to the botanist it has interest as throwing light upon the derivation of vegetable forms; and to the zoologist it offers an explanation of the diversities of animal life. The psychologist finds in it a key to the development of mind in all its grades, and the sociologist seeks its aid in tracing the progressive unfolding of the social state. By its most radical implication the "theory of evolution" excludes the view long and universally believed, that in all these spheres the phenomena were "specially created" as we now see them; and it asserts that in all these spheres the present effects have been brought about by gradual changes. The theory of "special creation" being abandoned, a theory of evolution is the inevitable alternative. And if the unity and harmonious interconnections of Nature, of which all science affords the proof, be not an illusion, then the "theory of evolution" must have a basis in the operation of universal principles, and must give rise to a general philosophical method of accounting for the present order of things. When, therefore, a man asks for information concerning the "theory of evolution," he can only be intelligently answered by referring him to the works where such a theory is presented. This, however, is not what the *Nation* does. It directs its correspondent first of all to Darwin's "Origin of Species" for the information he seeks. This is, of course, a great, original, and authoritative book; but it is, nevertheless, a special treatise on one branch of the subject of development, and, so far from making any attempt to expound the general "theory of evolution," there are whole phases of the subject that it does not touch. Nor does it attempt any such analysis of the problem, or resolution into its ultimate principles, as is necessary to the formation of a theory of the subject. Indeed, the very power and popularity of the work are, in a certain sense, due to its restriction, for it is mainly confined to the elucidation of a single principle. "Natural selection" was recognized before Mr. Darwin's time; what he has done is to show how this principle has acted in giving rise to new species from preëxisting species. It is a great thing to have done this, and Mr. Darwin is well entitled to his honors; but none the less is it misleading to cite his book on the "Origin of Species" as an exposition of the "theory of evolution."

Prof. Huxley has evidently had sub-

stantially the same question put to him as that directed to the editor of the *Nation*, but he returns to it a very different answer, while there is probably no living man better able to answer it. No one, certainly, knows more thoroughly the nature and extent of Mr. Darwin's contributions to the subject, or has a profounder appreciation of them, than he. And yet, in a lecture before the Royal Institution of Great Britain, Prof. Huxley said, after avowing his belief in the theory of evolution, "the only complete and systematic statement of the doctrine, with which I am acquainted, is that contained in Mr. Herbert Spencer's 'System of Philosophy'—a work which should be carefully studied by all who desire to know whither scientific thought is tending." Nothing can be more explicit or decisive, and, we may add, nothing more candid and just. Knowing perfectly all that Mr. Darwin had done, conversant as he was with the whole literature of the subject, foreign and domestic, he also thoroughly understood the claims of Mr. Spencer's contributions to the question, and his deliberate opinion, given to a critical audience, was, that whoever wanted information relating to the "theory of evolution" could *only* obtain it in a complete and satisfactory form from Mr. Spencer's works.

But the *Nation* thinks differently. It not only does not commend Mr. Spencer's works to readers seeking information on the "theory of evolution," but such readers are tacitly warned against them. Prof. Huxley, who ought to know what science is, recommends all who wish to understand the tendencies of scientific thought, to the study of Spencer's works; the *Nation* objects to Mr. Spencer as an expositor of science. A distinction is drawn between Darwin and Spencer, in which the former is characterized as "scientific and inductive," and the latter as "speculative." But this distinction is altogether groundless. Mr. Spencer's treatment of the problem of evolution is as rigorously inductive as Mr. Darwin's; but, if, to the inductive procedure, Mr. Spencer superadds the deductive, using established truths in an *a priori* way to strengthen and verify his conclusions, we hope that is not to be regarded as a contravention of true scientific method. The implication of the writer that Darwin gives the theory of evolution a firm inductive basis, while Mr. Spencer grounds it upon speculative *a priori* axioms, is as far as possible from being true.

Again, Mr. Spencer's works are contrasted with Darwin's by the writer in the *Nation* as treating of "general speculative philosophy in connection with theology and religion," while Mr. Darwin "nowhere considers scientific theses as either favorable or unfavorable to general philosophical or religious conclusions." Now, let us see what ground there is for this distinction. To a series of exhaustive works on evolution which were expected to run through a dozen volumes, there was prefixed an introductory part of 123 pages, the object of which was to define the sphere of science; and, in doing this, theology and religion were excluded from the discussion. And so this rejection of theology and religion becomes the basis of a charge that Mr. Spencer runs into theology and religion, in contrast to Mr. Darwin, who sticks to inductive science. It seems to be inferred that, because Mr. Spencer has designated his system of thought as a "philosophy," therefore he is chargeable with all the empty and baseless speculation which that term, in its old applications, connotes. But he clearly explains the sense in which he uses the term philosophy. By "philosophy" Mr. Spencer means actual, verifiable, scientific knowledge of the highest degree of generality. His philosophy, in its leading characteristic, is a synthesis or unification of the sciences, and it is

no more "speculative" than are the widest truths established in each of the sciences.

Again: the writer in the *Nation* points his contrast by characterizing Mr. Darwin's mental processes as properly Newtonian, while Mr. Spencer's are un-Newtonian. He says that Mr. Spencer has lately put forward the claim that "his method is justified by Newton's precepts and practice;" and he adds that, according to "the leading physicists of the day," this claim is not substantiated. Of this it may be said that Mr. Spencer put forth no such claims until he had been first attacked on this score by the Cambridge mathematicians; and "leading physicists of the day" are not wanting who regard the attack as a conspicuous failure. But, if the case is to go by the force of authority, does the writer in the *Nation* suppose that there are not plenty of "leading physicists of the day" who regard Mr. Darwin's method of reasoning as eminently un-Newtonian?

But to come back to the practical questions put by the correspondent of the *Nation*, we should say with Huxley that, if he wants information on the "theory of evolution" in any complete or adequate shape, he can find it in the works of Spencer more fully and systematically presented than anywhere else. He will find the theory expounded in the first volume of the "Philosophy;" and its biological, psychological, and sociological applications are elaborately presented in the subsequent divisions of the work. In Mr. Fiske's "Cosmic Philosophy" he will also find a masterly exposition of the whole subject, in its broad, philosophical aspects, complete in two volumes.

Darwin's various works are, of course, of great value, but they are voluminous, while Oscar Schmidt's newly published "Doctrine of Descent and Darwinism" is undoubtedly the best summing up of the discussion in the biological field that has yet been published. The works of Haeckel, translations of which will soon be printed, have the reputation of being learned and powerful, but they are limited to the field of zoology, and no more treat of the general "theory of evolution" than do the works of Darwin. The last edition of Lyell's "Principles of Geology" adopts the development theory and applies it to the course of geological life. The strongest books on the other side of the question are probably those of Agassiz, Mivart, and Dawson; and they are, moreover, moderate in size and popular in treatment. There are numerous other books of minor merit, like Lowne's and Henslow's "Prize Essays," but, unless a person has a passion for this kind of literature, and desires to pursue it in all its expressions, it will not be worth while to waste time and money on them when better works are procurable.

INCENTIVES IN EDUCATION.

We last month passed some strictures on the prevailing practice of stimulating educational competition by the offer of money-prizes. The defenders of the policy are, of course, not without their excuses, and the most plausible of them takes this form: "If life is an arena of competition—a struggle for existence—and the school is to be a preparation for life, how can the competitive element be excluded? Life has its prizes to be striven for; a few win and many lose. The school should teach the youth in its charge how to comport themselves under the strains of rivalry that will be put upon them in their subsequent social experience."

To this it may be replied that there are plenty of necessary strife and struggle in the school without superadding to them artificial provocatives. Classing always leads to comparison, and gradation to estimates of capacity which inevitably arouse self-regard, vanity, and the love of approbation.

The very organization of the school, its regular operations, and necessary daily results, are a constant and powerful appeal to the selfishness of the pupils. To be promoted, to beat some one, to outstrip a whole class in the open race, where the results are closely watched, is surely sufficient incentive, without throwing in medals and prizes to intensify the competition. Indeed, the strife, without these additional stimuli, is often far too strong, and requires to be checked by teachers and school-managers, instead of being encouraged and inflamed. Granted that the selfish motives are those by which people are habitually influenced in social life, it is the duty of teachers, and one of the great ends of education, to cultivate another class of motives, and to arouse and strengthen the more generous and disinterested feelings as incitements to action. In its highest purpose, the object of education is the formation of character, and character is the stamp of habitual feeling by which conduct is controlled. The common qualifications of a teacher are, to be able to "hear lessons," and to show children how to read, write, and cipher, but no teacher is fit for his business, in any adequate sense, who cannot discriminate among the gradation of motives by which pupils are influenced, and who cannot call out, exercise, discipline, and invigorate the higher motives that should operate in determining conduct. Undoubtedly we are drifting into a great system of wholesale machine-education, which deals with masses under general inflexible regulations, and in which the individual, as such, virtually disappears. The ambition is rather to drive all the children into the suffocating establishments called schools, and swell the numbers, and thus furnish materials for the National Bureau of Education, that it may flout its astonishing statistics in the face of an admiring world. American education thus takes its place in the category of "big things"—immense prairies, long railroads, universal suffrage, a mighty war, and the other elements of national vanity and boasting which the newspapers never allow us to forget. From this exalted place in the public regard, which our educational system has achieved, it is regarded as an eminent patriotic duty to patronize and encourage it, and so wealthy people can in no way better indicate their love of country, and minister to their own vanity, than by giving here a hundred dollars, and there five hundred, as prizes to be fought for in the schools. All this only aggravates an evil already too strong, and with which, from the very constitution of the schools, it is difficult to cope.

The education that does not recognize the individual and the elements of individuality as of the first importance, and cannot conform itself to their special and peculiar needs, and bring to bear effectually upon the widely-varying personalities with which it has to deal the incitements most suitable to each case, is, just to that degree, imperfect, and fails in the fundamental object of education. Education is a *leading out* of the faculties, and the very word determines the method. It is not a forcing out, a driving out, or a grinding out by machinery, but a process that expressly excludes the compulsive or coercive element—a *leading out*, which implies that the individual material to be acted upon has a nature that must be respected and acted upon in a given way. The preëxisting spontaneous forces of character, varying in their composition in each personality, are to be regarded by the educator, and are to shape his course, or he will fail of his highest object.

We say, then, that, first of all, the teacher should not be meddled with by thrusting in extraneous stimuli to give artificial excitement to the work of the school-room, and we are glad to see some symptoms of reaction against the old and vicious practice. Our edu-

cation has come to be so much a matter of demagogism and popular flattery that it will not be easy to carry out reform in this particular; but we welcome the indications that here and there appear, of a recognition of the existing evil and the need of its remedy. The following passage, which we have seen quoted from the late annual report of the able State Superintendent of Schools of Illinois, Mr. Newton Blakeman, although perhaps somewhat sanguine, at any rate rings out the truth:

"The era of shams, and cheats, and claptrap, in education, will have gone by. Rewards, and prizes, and other artificial and vicious incentives to study, will no longer be known, and with them the arbitrary, unjust, and preposterous practice of pretending to note a student's intellectual, moral, and deportmental rank and standing by a mechanical system of marks will also be numbered with the discarded rubbish of an obsolete educational dispensation. The hopes that have been crushed, the hearts that have been stung, the irreparable mischief that has been wrought by that puerile and abominable system, should have sent it to the moles and the bats long ago."

Equally encouraging is the action of the New York Board of Education in passing a resolution that hereafter no medals or prizes shall be accepted as awards to the students of the Normal College, except such as may have been previously founded, or from such persons as granted prizes prior to 1873. If this resolution be proper—that is, if the policy abandoned be bad—pray, why not abolish the existing prizes?

LITERARY NOTICES.

THE CHEMISTRY OF LIGHT AND PHOTOGRAPHY, IN ITS APPLICATIONS TO ART, SCIENCE, AND INDUSTRY. By Dr. HERMANN VOGEL, Professor in Berlin. 100 Illustrations. Pp. 290. D. Appleton & Co. No. XIV. of the "International Scientific Series."

At the International Convention of Photographers, held in this country a few years ago, Dr. Hermann Vogel, of Berlin, was the distinguished German delegate, and was much honored as one of the most eminent and successful cultivators of the subject in both its scientific and artistic aspects. Perhaps no man in any country was so well prepared to make a thorough presentation of the principles and practice of this beautiful process, and, upon being applied to to write a book upon the subject for the "International Series" he consented, and the volume now before us confirms the wisdom of the application. It is worthy the reputation of the author and the interest of the subject, and is beyond comparison the best popular treatise on the chemistry of light, and the present state of the arts that have grown out of it, that has yet been produced. The history of the efforts, by scientific men, in the early part of the century, to fix and preserve in some way the images formed by light, is familiar to all. Davy and Wedgwood, of England, made the earliest attempts, in 1802, to secure such lasting impressions. Their results, however, were very imperfect, and from time to time the problem was attacked by other chemists, and was finally solved by Niépce and Daguerre, and the process was given to the world in 1840. In the light of all that has been done in the past thirty-five years, the little pictures of Daguerre, with their "ugly, mirror-like dazzle, which prevented a clear view of them," are now regarded as insignificant, but they were at first contemplated with wonder. When, however, the process was once securely possessed, it was rapidly improved and extended, until it has now become an important element of civilized life. As Dr. Vogel remarks, photography has "spread over almost every branch of human effort and knowledge, and now there is scarcely a single field in the universe of visible phenomena where its productive influence is not felt. It brings before us faithful pictures of remote regions, of strange forms of stratification, of fauna, and of flora; it fixes the transient appearances of solar eclipses; it is of great utility to the astronomer and geographer; it registers the movements of the barometer and thermometer; it has found an alliance with porcelain-painting, with lithography, metal and book typography; it makes the noblest works of art accessible to those of slender means. It may thus be compared to the

art of printing, which confers the greatest benefit by multiplying the production of thought, for it conveys an analogous advantage by fixing and multiplying phenomena. But it does more than this. A new science has been called into being by photography, the Chemistry of Light; it has given new conclusions respecting the operations of the vibrating ether of light. It is true that these services, rendered by photography to art and science, are only appreciated by the few. Men of science have in great measure neglected this branch, after the first enthusiasm excited by Daguerre's invention had evaporated; it is only cursorily that physical and chemical matters are treated on in manuals of photography."

The interest of Dr. Vogel's volume is not at all confined to the treatment of that side of the subject which is important to practical operators. It will be equally appreciated by the multitudes of people who are buyers of photographs, and who not only desire to understand the processes by which they are produced, but to know what are the excellences and defects of photographic productions, and how they are to be intelligently criticised. We print a portion of one of Dr. Vogel's chapters upon this branch of the subject.

SCIENTIFIC LONDON. By BERNARD H. BECKER. New York: D. Appleton & Company, 1875, 340 pages. Price, $1.75.

SOME one has cleverly pointed out the tendency of all Anglo-Saxons to organize themselves into committees with a president, a vice-president, two secretaries, and a treasurer, before they can do any work, great or small, or indeed before they feel ready to deliberate in concert. We are familar enough with this in America, and we are ready enough to laugh at the extreme to which it is carried; but our English brothers, and peculiarly our English scientific brothers, carry this even further than we do.

Witness the list of the meetings of the scientific bodies of London which are announced in *Nature* weekly. It is worth while to transcribe some of the most important names:

The Royal Society, the Royal Institution, the Society of Arts, the Institution of Civil Engineers, the Chemical Society, the Department of Science and Art, the London Institution, the Birkbeck Institute, the Society of Telegraph Engineers, the Museum of Practical Geology, the British Association, the Statistical Society, the Royal Geographical Society—all the foregoing societies are spoken of in Mr. Becker's book, while there yet remain of the important societies—the Mathematical Society, the Society of Antiquaries, the Royal Astronomical Society, the Entomological, the Zoological, the Asiatic, the Meteorological, the Geological, the Linnæan, the Royal Microscopical, the Royal Horticultural, the Royal Botanic Societies, and quite a number of others, hardly less important—the Society of Biblical Archæology, and the Geologists' Association, for example.

This is a curious and a very instructive list. It shows that year by year the specialists in each branch feel obliged to bring themselves closer together in order to keep pace with the advances in their peculiar subject; and it illustrates well the great share which the scientific societies of England have in forwarding and promoting scientific work. There is undoubtedly a great deal of good done by this system, for each of the minor societies has in it several of the great men of the nation, whose influence is thus exerted, not only upon the Royal Society (of which they are, of course, members), but upon a host of younger and less celebrated men who are elevated by the contact.

The system has, too, an injurious effect which is equally apparent: the great men become "scientific popes" in the eyes of their associates, and the ignoring of every thing foreign—the "insularity"—of Englishmen, which has become a byword in ordinary matters, is specially fostered in science, where of all places it is most noxious.

Thus, to an Englishman, *De la Rue* is, and always will be, "the father of celestial photography," notwithstanding Draper and Bond: and it is so in many other cases. But, in spite of this, the great and small societies are a powerful and helpful force in England, and they contain a galaxy of distinguished names, which may well make any country proud.

Mr. Becker in his interesting little book gives us a glance into several of these great societies, or rather he takes us into his club, and, making himself and his reader very comfortable, he proceeds to chat with agreeable frankness about what he has seen, about what interests him, whether it be the theory of isomeric alcohols, or the way the pretty girls of the London audiences are dressed. Once in a while he seems to feel that he is growing trivial, and drawing forth a memorandum he gives a long (and useful) array of facts and figures. But these occasions are rare; he tells his listener very pleasantly what he has seen in the various scientific companies, what he thought, and what he knows about them, what amused him and what bored him. Almost every one will enjoy his easy talk, and almost every one will learn something from his book. His view of science and scientific men is not precisely the highest nor the most dramatic one. Huxley is one of those who have helped "to gild the pill of science," not a strong man earnestly striving for what he thinks the right and true. Tyndall is quite the same—the enthusiasm, the "sacred rage" in them is quite left out; they are simply men in dress-coats who are successful, eminent, and highly to be respected.

The English astronomer Smyth tells us in one of his fascinating books of a visit which he made to Encke at the Berlin Observatory, and he seizes so well the dramatic side of the situation that his reader almost hears, as he did, the astronomical clock ticking off the seconds which but just now belonged to eternity and are lapsed into time.

To Mr. Becker, Encke would have been an eminent observer and astronomer, and the secretary of the Berlin Academy; and his clock would have been in a mahogany case, and would have cost £100 0s. 0d.; but Mr. Becker's account of the Berlin Observatory would have been worth listening to. Indeed, it is hardly fair to object even in the least to the manner of the book, since its pretensions are so modest and its facts and figures so good; and we are sure that all of Mr. Becker's readers will thank him for the quiet enjoyment he gives them in his 340 pages of pleasant talk.

A PRACTICAL TREATISE ON THE GASES MET WITH IN COAL-MINES. By the late J. J. ATKINSON, Government Inspector of Mines of the County of Durham, England. 53 pp. Price 50 cents. New York: D. Van Nostrand.

THE author of this little monograph was an authority upon the most complicated questions of ventilation, and the President of the Manchester Geological Society declares it to be "the most useful book of reference yet published on the ventilation of mines."

The discussion is unquestionably of very great interest to all who have the management of mines, or are exposed to danger from ignorance of the nature of the gases that are set free in subterranean explorations. But the little book seems not without interest to others. The laws of atmospheric change, and their relations to life, are general, and the practical problem of ventilation, as we encounter it every day in our dwellings, is by no means simple. There is much information in this little manual relating to the air we breathe, its pressures, movements, vitiations, and various properties, which is of general interest and importance.

OBSERVATIONS OF SUN-SPOTS AT ANCLAM. By Prof. G. SPOERER. With 23 Lithographic Plates. Publications of the (German) Astronomical Society, No. 13. Leipsic, 1874.

WE have had occasion to call the attention of our readers, from time to time, to various popular works on the physical condition of the sun ("The Sun," by Proctor, Lockyer's "Solar Physics," etc.), and we now desire to note the appearance of this great work of Dr. Spoerer's, which, with Carrington's "Observations of the Spots on the Sun," forms the basis upon which future theorists must build.

Carrington's accurate observations commenced in November, 1853, and since that time the solar surface has been assiduously observed by Carrington, Spoerer, Wolf, Secchi, De la Rue, and others, in Europe, and by C. H. F. Peters, Winlock, and Langley, in America. Photographic records of the sun-spots have been made in America, in England, and in Russia; and Germany has just established an observatory at Pots-

dam which will be exclusively occupied with sun-observations.

Carrington's work covered the period 1853–1861, and Spoerer's extended from 1861 to 1871, and was done on much the same plan. He, of course, confirms the discovery by Carrington of the law which declares that the velocity of the rotation of the outer layer of the sun's surface is greatest near the sun's equator and diminishes gradually toward the poles, and he arrives at other conclusions, a few of which we will give, as generally interesting, referring students of astronomy to the original work. It is well known, from the recent observations (since 1853), that Schwabe's discovery is true that the *number* of spots on the sun's disk is governed by some periodic cause which produces a maximum number and a minimum number of spots every eleven years. It is probable that magnetism, rainfall, and temperature, and other terrestrial phenomena, are connected with this period of eleven years, the cause of which is as yet unknown.

Spoerer has discussed the observations of the spots separately for each half (i. e., northern and southern) of the solar disk. He finds (page 137) that the points of maximum and minimum frequency of spots are reached *earlier* in the *southern* hemisphere of the sun. "While the minimum of the year 1856 still lasted in the northern hemisphere, the increase (in the number of spots) had already begun in the southern hemisphere, and had here in 1858 reached a maximum," while in the northern hemisphere the maximum began in 1860. The *mean* heliographic latitude of the spots, however, shows "no characteristic difference between the two hemispheres."

In the eleven-year period (1854–1864) the ratio of the number of spots in the northern hemisphere to the number in the southern was 933 : 1,000; from 1861–1871 this ratio was 976 : 1,000. The spots on the sun give a means of determining the velocity of the sun's rotation, but the determination of this element is complicated by the fact that these spots have a *drift* or proper motion in longitude. Spoerer finds the angle through which the sun rotates in one day to be 14° 16′ nearly, while Carrington determined this element to be 14° 11′; that is, Spoerer fixes the time of the sun's rotation on its axis as 25 days, 5 hours, 37 seconds. This mean value—14° 16′—is, however, subject to change, and Spoerer suggests that further investigations may show that the changes which are known to occur in this value may be found to occur earlier in that hemisphere of the sun which has, at the time, the greatest spotted area. This question it will require *several* eleven-year periods to settle.

It is to be hoped that these most valuable researches will be continued, and that America will contribute her full share to the labor. There is a sure reward awaiting investigators in this field.

THE ELEVATIONS OF CERTAIN DATUM-POINTS ON THE GREAT LAKES AND RIVERS, AND IN THE ROCKY MOUNTAINS. By JAMES T. GARDNER, Geographer (from the Report of the United States Geological and Geographical Survey of the Territories for 1873). Washington: Government Printing-Office, 1875.

IN this modest pamphlet of thirty pages Mr. Gardner has made a very valuable step toward utilizing a vast quantity of material which has until now been little employed. Every railroad or canal has been located only after one or two lines of leveling have been run between its terminal points, and a mere glance at a railroad map of the United States will show what an immense collection of data exists for the determination of the altitude of any point on any railroad.

A complete discussion of this has not been attempted, Mr. Gardner's principal object having been to determine the altitude of Denver, in Colorado, above the mean level of the Atlantic Ocean, Denver being the point to which the altitudes determined by the survey of the Territories are referred.

Incidental to this object, results of great interest have been obtained, a few of which will be mentioned. The material for the work was necessarily of the most varied character and of many degrees of accuracy, from the first trial-lines of reconnaissance-surveys to the final releveling of a finished railroad or canal. Great care was necessary in selecting from the reports of chief-engineers and elsewhere the right figures, and in giving proper weights to these when

selected. The chief difficulty, however, was in joining the ends of various lines, each referred to separate points.

The author personally visited many of these terminal points, and had new determinations made when necessary. That he has succeeded may be seen from his results for the altitude of Denver, derived from the lines of the Kansas Pacific and Union Pacific Railroads. This altitude is 5,198.97 feet by the Kansas Pacific Railroad surveys, and 5,194.20 feet by the Union Pacific Railroad surveys, a difference of less than *five feet* in lines nearly 2,000 miles long, which were run at different times, by many different engineers.

In the eastern part of the United States there are many opportunities to check such results in places situated on two or more roads, and the examination of a few such checks will serve to give an idea of the agreement to be expected. At Harrisburg, for example, we have two lines of level, one brought by the Coast Survey and the Pennsylvania Railroad from Raritan Bay (175 miles), and the other from Baltimore by the Northern Central Railroad. The first gives 319.91 feet, the second 319.75. This agreement is rather closer than could be expected, and, although the author does not mention it in this connection, it is subject to an uncertainty in the determination of mean tide at Baltimore, noted further on.

The height of the Chicago city directrix above mean tide, as determined by the surveys of the Pennsylvania Railroad and its connections (900 miles), is 585.41 feet; from the surveys of the New York Central Railroad and connections 587.57, and this agreement is perhaps a fair type of what we may expect from surveys conducted with care over long-established railway-lines.

We will adduce one more example, determining the elevation of the mean surface of Lake Erie: the independent results are 573.08, 572.04, 572.67, 570.75, 571.67, and [581.20]. The last determination is rejected on the testimony of the chief-engineer of the railroad from whose surveys it is given.

Mr. Gardner states, as the results of his experience, that most of the errors found are produced by hasty computation and careless combination of results, rather than by imperfect instrumental work. This is shown by his own careful combinations to be the case, since we cannot consider the agreement he has found as fortuitous. He recommends civil-engineers to connect their surveys with the city-directrices and to send a copy of their profiles to the Signal-Office in Washington, so that their careful work may be made of scientific use, by suitable discussion.

As the results of this investigation Mr. Gardner announces that the great lakes and the surrounding country are now recorded 9 feet too low, St. Louis 23 feet too low, Kansas City 100 feet too low, Indianapolis 100 feet too low, and Omaha 31 feet too low.

These corrections rest on various data, and are not all of equal certainty, but they must be accepted for the present. The whole subject must eventually be thoroughly discussed; until it is, this valuable research will be the standard.

POLARIZATION OF LIGHT. By WILLIAM SPOTTISWOODE, M. A., F. R. S., etc. New York: Macmillan, 137 pp. Price $1.00.

THE diffusion of Prof. Tyndall's "Lectures on Light" in tens of thousands of copies throughout the United States has awakened a popular interest in even the more abstruse questions connected with that topic. Mr. Spottiswoode's little volume is devoted to the phenomena of polarization, which it discusses in a style adapted for popular comprehension. The method of the book is synthetic—the phenomena of polarization and its different processes are first brought before the mind of the reader in a number of experiments (which are fully illustrated); then the author explains what is meant by the undulatory theory of light. The phenomena of polarization are seen to accommodate themselves so thoroughly to this theory, that a simple approximation of the two is sufficient to prove that the one is the *law* of the other. Having thus coördinated the phenomena, the author considers in separate chapters "Circular Polarization," "Phenomena produced by Mechanical Means," "Atmospheric and other Polarization," "Figures produced by Crystal Plates," and "Composition of Colors by Polarized Light." The subject last named is illustrated by means of two very beautiful chromo-lithograph plates.

WHAT IS MUSIC? By ISAAC L. RICE, Author of "Analysis and Practice of the Scales." 94 pp. Price 50 cents. New York: D. Appleton & Co.

THIS is an ingenious essay by a musical professor who not only practises the art, but speculates freely and boldly upon its nature and origin. The theories of music which have been hitherto proposed do not satisfy him, and he is inclined to consider that the ancients were nearer right in their views of the subject than the moderns. The contrast between the ancient and the modern stand-points he takes to be, that the ancients looked upon music cosmically, or considered it a part of Nature, while the moderns are more disposed to regard it as something subjective. The first half of the work is devoted to an exposition of the various theories that have been proposed —Chinese music, Hindoo music, Egyptian, Grecian, Arabic, and Persian theories, and its scholastic interpretations in the middle ages. The doctrines of Euler, Helmholtz, and Herbert Spencer, are reviewed, and with the latter author Mr. Rice takes issue on many of his positions. The latter half of the work is devoted to a presentation of his own views of the subject. His idea seems to be that, as beauty of form or color is a principle of Nature, displayed in space, so music is a principle of beauty in Nature displayed in time. The key to the author's position is given in the following passage:

"Now, *what is music?* The *beautifier of time*, is the simple and categorical answer—an answer, too, from which further answers to all questions springing from the original question may be deduced; an answer that serves as the corner-stone of the fundamental theory of music itself. It is to adorn the ever-moving space of existence that music was generated and the germs of its development were placed within it. In the space of rest, in visible Nature, Nature itself has undertaken the task of beautifying. And there she has lavished beauties untold and unnumbered. Beauty reigns on the mountain and in the valley, on the hill and in the dale. It is present in the gentle grove as well as in the mighty forest. It is in the little brook and in the magnificent ocean. It is in man and woman, in the birds, in the plants—anywhere, everywhere, it meets our eyes, if we will but see. There are beauties of all kinds and degrees, from the sublime to the graceful, from the magnificent to the picturesque. All this has Nature done for space—and to do something similar for time is the grand and holy object of music. The materials of which music is composed exist only in Time, and here we have the explanation of many of the characteristics of music. Time is motion, is life, yet the sure bringer of change, of death. As it is motion, its influence upon us is emotional, agitating; as it constantly tells us of change and death, it awakens the feelings of melancholy within us. Music, as it beautifies the passing moments, yet tells us that they are passing, and consequently it is so prone to cause sadness."

Without indorsing Mr. Rice's views, which seem to us rather fanciful, his little work will be found suggestive, and contains withal much curious information that will interest the lovers of musical literature.

CHEMICAL EXAMINATION OF ALCOHOLIC LIQUORS. A Manual of the Constituents of the Distilled Spirits and Fermented Liquors of Commerce, and their Qualitative and Quantitative Determination. By ALBERT PRESCOTT, Professor of Organic and Applied Chemistry in the University of Michigan. 108 pp. Price $1.50. New York: D. Van Nostrand.

THIS volume concentrates the rays of the latest chemical science upon the subject of spirituous liquors. The author has nothing to say of the physiological, pathological, or moral effects of alcoholic beverages, but occupies himself simply with the question of their composition, production, constituents, and imitations; and his book being written under no bias, but simply to state the scientific facts, may be taken as entirely trustworthy. Its especial value will be to chemists who may be required to investigate the constituents and the purity of alcoholic liquors.

ELEMENTS OF MAGNETISM AND ELECTRICITY. By JOHN ANGELL. 172 pp. Price 75 cents. New York: Putnams.

THOUGH the author's purpose is to fit students to "pass in the first class in the elementary stage of the government science examinations" for aspirants to position in the civil service of Great Britain, the work has a value of its own, as being a succinct statement of the sciences of magnetism and electricity.

PRINCIPLES OF METAL-MINING. By J. H. COLLINS, F. G. S. 150 pp. Price 75 cents. New York: Putnams.

THE object of this little work is to convey some elementary knowledge of the principles and facts of mining in a form suitable for the instruction of young miners. It teaches them what to observe, and how to interpret their observations.

THE TREATMENT OF NERVOUS DISEASES BY ELECTRICITY. By Dr. FRIEDRICH FIEBER. Translated by George M. Schweig, M. D. 64 pp. Price 75 cents. New York: Putnams.

THIS little treatise is addressed to the medical profession. It aims to set forth the many advantages of electro-therapy, with a view to popularizing it among medical men.

THE CULTIVATION OF ART, AND ITS RELATIONS TO RELIGIOUS PURITANISM AND MONEY-GETTING. By A. R. COOPER. 48 pp. Price 25 cents. New York: Charles P. Somerby.

A THOUGHTFUL, earnest, temperate plea for æsthetic culture.

ANTIQUITY OF CHRISTIANITY. By JOHN ALBERGER. 61 pp. Price 35 cents. New York: Charles P. Somerby.

THIS is an attempt to trace the distinctive dogmas of the Christian religion to heathen originals.

PUBLICATIONS RECEIVED.

Astronomical and Meteorological Observations made during the Year 1872 at the United States Naval Observatory. Pp. 550. Washington: Government Printing-Office.

Annual Report of Lieutenant Wheeler's Geographical Explorations for 1874. Pp. 130. Washington: Government Printing-Office.

On the Muridæ. By Dr. Elliott Coues, United States Army. Pp. 28. Philadelphia, 1874.

Invertebrate Fossils collected by Wheeler's Expeditions of 1871, 1872, and 1873. By C. A. White, M. D. Pp. 27. Washington: Government Printing-Office.

Theory of Education in the United States of America, pp. 22; *and* National Bureau of Education, pp. 16. Washington: Government Printing-Office.

Migrants and Sailors in their Relation to the Public Health. By Drs. John M. Woodworth and Heber Smith. Pp. 21. Cambridge: Riverside Press.

Report of the Commissioners of Lunacy to the Commonwealth of Massachusetts (1875). Pp. 79.

A Guide to the Practical Examination of Urine. By James Tyson, M. D. Pp. 182. Price, $1.50. Philadelphia: Lindsay & Blakiston.

Report of the Trustees of the Building-Fund of the Philadelphia Academy of Sciences. Pp. 24.

Prison Association of New York. Thirteenth Annual Report. Pp. 23.

Report upon the Sanitary Qualities of the Sudbury, Mystic, and other River Waters. Pp. 108. Boston, 1874.

Ohio State Medical Society. President's Address (1874). Pp. 16.

Alimentation. By S. A. C. Hamlin, M. D. Pp. 23.

Hand-book of the Kansas Agricultural College. Pp. 124. Manhattan, Kansas, 1874.

Notes on the Natural History of Portions of Montana and Dakota. By J. A. Allen. Pp. 61. Boston, 1874.

Annual Report of the Treasurer of the United States for the Fiscal Year ended June 30, 1874.

The Transmission of Sound by the Atmosphere. By Tyndall. Gigantic Cuttle-Fish. By Saville Kent. Pp. 32. Price, 25 cents. Boston: Estes & Lauriat.

Municipal Law, and its Relation to the Constitution of Man. By R. S. Guernsey. Pp. 11.

Man and Nature. By Dr. Samuel W. Francis. Parts III. and IV. Pp. 28 and 15. Newport, R. I.: C. E. Hammett.

Modern Thought and Ancient Dogmas. Nos. 1 and 2. Pp. 21 and 28. San Francisco, 1875.

MISCELLANY.

Capture of a Herd of Elephants.—A correspondent of *Land and Water* tells of the capture, in the Mysore district, India, of a herd of elephants, numbering forty-nine head. An irrigating canal winds through a dense jungle, at some points approaching a small river, at others stretching away from it into the jungle. In one place a bend of the canal forms, with the river, an inclosure in the shape of a horseshoe, containing about fifteen acres of wooded ground. To this place elephants resort during the monsoon, crossing the canal at three or four points where the banks have become trodden down by constant use. In order to trap the entire herd, two lines of chains were stretched across the river at the ends of the horseshoe, and a trench was dug on the river-bank to cut off escape on that side. The elephants having crossed into the inclosure, the fords were barricaded with cocoa-nut trees, the canal deepened at those places, and two deep trenches cut from the canal to the river. Fires were kept up at night on the banks of the canal. Meanwhile a deep, circular trench was dug, inclosing about an acre of ground, and two parallel trenches were also dug, leading from the horseshoe to this small inclosure. Drop-gates were made to prevent the animals leaving this *keddah* when once they had entered it.

A large force of men were now directed to drive the herd into the *keddah*. The first attempt failed, the elephants stampeding back into the horseshoe after a few of them had entered the inclosure. A second effort was crowned with success. First came a female with her calf; then seven other females, and after a while on came the entire herd with a rush, males, females, and calves, of all sizes, "like a herd of rather large pigs, jostling and pushing one another through the gate-way." When the last was in, down went the gate, and they were all secured. The catching of the elephants one by one was the work of several days. "The men ride in among them on tame beasts, and put ropes round their legs and necks, after which the tame elephants drag them out in spite of all resistance, and they are chained one by one to trees to be trained at leisure. They do not mind the tame elephants mixing with them at all, even with men on their backs, but they object strongly to the men on the ground, who have to put on the ropes. The clever way in which the tame elephants help is wonderful: they move close up to the wild ones, and understand how to put their legs so as to shield the men from all kicks; they take hold of the wild ones' legs and trunks with their own trunks, and are invaluable."

Habits of the Cotton-Worm.—According to Mr. Aug. R. Grote, the cotton-worm dies out every year, with its food-plant, and its next appearance is always the result of immigration. He has observed that the appearance of the worm in the cotton-fields is always heralded by flights of the moth. The worm is always heard of to the southward at first, and never to the northward of any given locality in the cotton-belt. Mr. Grote never could discover any traces of the insect in any stage during the months *preceding* the appearance of the first brood heralded by the moth, and *after* the cotton was above the ground. Hence he concludes that while the cotton-plant is not indigenous to the Southern States (where it becomes an annual) the cotton-worm moth may be esteemed not a denizen but a visitant, brought by various causes to breed in a strange region, and that it naturally dies out in the cotton-belt, unable to suit itself *as yet* to the altered economy of its food-plant and to contend with the changes of our seasons. Possibly in the southern portions of Texas, or in the Floridian peninsula, the cotton-worm may be able to sustain itself during the entire year. Its true home, however, appears to be the West Indies, Mexico, and Brazil, where the cotton-plant is perennial.

Coal in California.—Dr. J. C. Cooper, formerly connected with the State Geological Survey of California, made some interesting remarks at a late meeting of the California Academy of Sciences on the subject of California coal. The frequent reports in the newspapers of discoveries of valuable coal deposits in different parts of the State he characterized as misleading,

not more than one in a hundred of such so-called coal-beds having any value whatever. Unlike the true coal of the carboniferous rocks formed from tree-ferns, algæ, and other plants of low organization, that of the Pacific coast contains the remains of coniferous and dicotyledonous trees, and belongs to the cretaceous rocks, or is of even later origin. It is the lignite of geologists. Many of the beds of this material are too thin to work, a thickness of two feet being the minimum that can be economically taken out. For all practical purposes this lignite in many localities is as good as the older coal, but the thinness of most of the beds makes them useless as sources of supply.

How the Amœba takes its Food.—Prof. Leidy has observed an amœba in the act of taking in its food, and, at a recent meeting of the Philadelphia Academy of Sciences, showed that these curious animals, at least in some instances, employ their pseudopods as instruments for capturing the minute creatures on which they prey. It has commonly been supposed that the amœba's food simply sticks to its body and "falls through" into the stomach-sac. Prof. Leidy saw the two pseudopods of an *Amœba princeps* gradually approach, come in contact, and then actually become fused—thus securing between them a flagellate infusorium. The infusorium continued to move back and forth, endeavoring to escape. "At the next moment a delicate film of the entosarc proceeded from the body of the amœba, and gradually extended outwardly, so as to convert the circle of the pseudopods into a complete sac, inclosing the infusorium."

A Fresh-water Sponge.—At a recent meeting of the New Jersey Microscopical Society, at New Brunswick, its Secretary, Prof. Lockwood, exhibited specimens of a fresh-water sponge, discovered by himself in a pond at Port Republic, New Jersey. The sponge grew in masses, covering several square yards of surface, with a thickness varying from an inch to two inches. It has a dichotomous habit of growth, and the sarcode, or sponge-flesh, was of an intensely dark-green color. It seemed quite closely related to the *Spongilla fluviatilis*. Some slides were shown with the spicules cleaned by treatment with boiling nitric acid. With a new lens of low power (seventy-five diameter), just made by George Wale, and of most excellent definition, the silica-spicules were finely brought out. They are cylindrical, curved, and pointed at both ends. They are limited to one form, and are arranged in little fascicles of about twelve spicules in each bundle.

A. Crum Brown on Chemical Theory.—In his address, as President of the Chemical Section of the British Association, Dr. A. Crum Brown defined chemical constitution as the order in which the constituents are united in the compound, and pointed out that the study of chemical changes (composition and decomposition) cannot lead us to a knowledge of the relative position of the atoms. But such a knowledge is required before a real theory of chemistry can be attained, and a knowledge of the intimate structure of matter may be looked for from an examination of the physical properties of substances, and a comparison of these with their chemical constitution. This, he maintained, is truly a branch of chemistry, and the greatest progress in it had been made by chemists, as might be proved by reference to the works of Faraday, Graham, and Andrews. By pursuing this branch, discoveries might be made which would lead to an hypothesis directly connecting chemistry with dynamics, and enabling us to apply mathematics directly to chemistry. The theory of chemistry would then be a particular case of the theory of dynamics. Such a result must be expected by all who believe in the progress of human knowledge and in the consistency of Nature.

Changes attending the Process of Germination.—In the course of their researches on germination, Messrs. Dehérain and Landrin have discovered that, when moist seeds are kept for two or three days in a closed tube above a column of mercury, the volume of air decreases even before carbonic acid has made its appearance. Moist seeds have, therefore, the property of condensing gases after the manner of porous bodies. But no gas can lose the aëriform state without at the same time giving up

some of its latent heat; and it is precisely this disengaged heat which raises the temperature of the oxygen to such a degree that it begins to attack the tissues of the seed, and to awaken the life which lay dormant in it. The authors hold the mechanism of germination to be as follows: 1. Softening of the seed-envelopes by water; 2. Penetration of gases and disengagement of heat; 3. Alteration of the principles contained in the seeds by the heated oxygen. A memoir, giving full details on this subject, will shortly appear in the "French Annals of the Natural Sciences."

Marvine's Survey of Western Colorado.—From a letter of a *New York Times* correspondent, we take the following notes of the survey of Western Colorado, by Marvine's division of Hayden's exploring party: The most interesting section visited was the high *mesa* lying near the head of the White River. This mesa is nearly 1,000 miles in extent, and has an average altitude of about 12,000 feet. A large portion of it is a lava-bed, with innumerable lakes scattered over its whole extent. The influence of these lava-beds on the climate of this section is very marked. The party reached the mesa about the middle of September; it was almost enveloped in clouds; there were about four inches of snow, and the thermometer was down to 6°. The clouds lay on the mesa for weeks, though in the valley it was clear. On the east the mesa descends in precipitous slopes to the flats in Egeria Park; on the west the great lava plateau gradually falls and becomes well timbered, chiefly with spruce; the lava-top ceases, and is replaced by the sedimentary rocks rising from beneath it. The White River country, lying north of the mesa, constitutes the Ute Indian Reservation, and is described by Marvine's party as a grand hunting-ground, with game in abundance, plenty of water and timber, and large areas of fertile soil. It is the best portion of Colorado west of the Parks. The country in Egeria Park, east of the mesa, abounded in a great variety of beautiful wild-flowers, and raspberries of rich flavor. Mr. Barber, the botanist of the party, secured a large and rare collection. Toward the western limit of the region explored, excellent coal began to appear, with the promise of much beyond.

Voelcker on the Quality of Milk.—Dr. Voelcker, who holds high rank in England as an agricultural chemist, asserts that, owing to the natural variations in the quality of milk, it is utterly impossible, in all cases, to ascertain whether a small quantity of cream has been removed from milk, or an inconsiderable proportion of water added to it. As the result of his own experience, he states that milk may be considered rich when it contains 12 per cent. of solid matter, of which 3 or 3½ are pure butter. If it contains over 12½ per cent. of solid matter, and has 4 per cent. or more of fat, it is of extra-rich quality. Good milk, of fair average quality, contains from 10½ to 11 per cent. of dry matter, including about 2½ per cent. of pure fat. Poor milk contains 90 per cent. or more of water. If milk is both skimmed and watered, it yields less than 4 per cent. of cream, and its specific gravity is about 1.025. A great many experiments have led the author to the conclusion that, within certain limits, the specific gravity is the most trustworthy indicator of quality. Some of the objections to the use of hydrometers are based on the mistaken opinion that cream is lighter than water. It is lighter than milk, but, compared with water, it is as 1.012, or even 1.019 to 1.000. A low specific gravity thus always indicates a large proportion of water. From sundry observations, it appears that good, pure milk has a specific gravity of 1.030, skimmed milk being a little lighter; and, further, that milk with a specific gravity below 1.025 is either mixed with water, or is naturally very poor. A useful instrument for approximately determining the percentage of cream is a graduated glass tube, at the top of which the cream may be allowed to collect, and its quantity may be read off.

The Royal Society of Great Britain.—The origin of the English Royal Society is related as follows in the "Memoirs of the French Academy." We give the passage as translated in *Nature*: "Full fifty years had elapsed (in 1666) since the learned men who lived in Paris began to meet at the

abode of Father Mersenne, who was the friend of the most learned men in Europe, and was pleased to be the centre of their mutual visits. Messieurs Gassendi, Descartes, Hobbes, Roberval, Pascal (father and son), Blondel, and some others, met at this place. The assemblies were more regularly held at M. de Montmort's, Master of Request in Parliament, and afterward at M. Thevenot's. A few foreign visitors to Paris were present at these meetings.... It is possible that these Paris assemblies have given birth to several academies in the rest of Europe. However, it is certain that the English gentlemen who created the Royal Society had traveled in France, and had visited at Montmort's and Thevenot's. When they were again in England they held meetings at Oxford, and kept on practising the exercises to which they had been accustomed in France. The rule of Cromwell was beneficial to these meetings. These English gentlemen, secretly attached to their legitimate lord, and unwilling to take any part in public affairs, were very glad to find an occupation which would give them an opportunity of living far from London without being suspected by the Protector. The Society remained in this state up to the time when Charles II., having resumed the kingly office, brought it to London, confirmed it by his royal power, and gave it privileges. So Charles II. rewarded the sciences which had lent an easy pretext for keeping the faith toward him."

Vitality of Seeds.—Two years ago a few peas, in a very dry and hard state, were found in a sarcophagus containing a mummy, in the course of certain excavations going on in Egypt. The idea was conceived of testing the vitality of these peas, buried as they had been for thousands of years. Three of them were planted, which grew and produced enough to cover, in the year following, a considerable field. Some of of the stalks reached a height of more than six feet, and attained a size which was altogether extraordinary, and a strength which rendered them self-supporting. The flowers were white and rose-colored, and of delicious freshness. The pods were grouped on either side of the stalk, in a sort of circular zone toward the top, and not regularly distributed throughout the plant, as in the common pea. It is believed by those who have examined this ancient pea and tested its edible qualities that it belongs to the family of the ordinary pea of our gardens, but that it is a special variety distinguished by the characteristics above mentioned in regard to the form of the stalk and the disposition of the pods.

In corroboration of the fact that seeds will retain their vitality for an indefinite period when embedded deep in the earth, Prof. von Heldreich, of Athens, Greece, states that on the removal of the mass of slag accumulated in working the Laurium silver-mines, some fifteen hundred years ago, a quantity of a species of *glaucium*, or horn-poppy, has made its appearance; and, what is remarkable, it proves to be a new and undescribed species to which the name *Glaucium serpieri* has been given. Prof. Niven, of the Hull Botanic Garden, England, in further corroboration of the same fact, mentions several instances of extraordinary vitality of seeds, from his own observation, and remarks that, "Doubtless the absence of air, an equable and unvarying condition as regards moisture and temperature, and above all the complete neutralization of the physical influence of the sunlight, constitute the means by which Nature exercises a preservative power in seeds as astounding as it is interesting."

To the above might be added the fact so well known to the farmers of Monmouth County, New Jersey, that the green-sand marl sown upon lands almost sterile "brings in white clover" (*Trifolium repens*) where it was not known before.

Recent Observations of the Planet Venus.—Some eight years ago Prof. C. S. Lyman communicated to the *American Journal of Science* a brief notice of some observations made on Venus when near her inferior conjunction in 1866. So far as appears, the planet was then for the first time seen as a very delicate luminous ring. An opportunity of repeating these observations presented itself on the occasion of the recent transit, and Prof. Lyman has another communication upon the subject in the same journal. "On Tuesday, December 8th," he writes, "Venus was again in close prox-

imity to the sun, and the writer had the satisfaction of watching the delicate, silvery ring inclosing her disk, even when the planet was only the sun's semi-diameter from his limb. This was at 4 P. M., or less than five hours before the beginning of the transit. The ring was brightest on the side toward the sun—the crescent proper. On the opposide side the thread of light was duller and of a slightly yellowish tinge. On the northern limb of the planet, some 60° or 80° from the point opposite the sun, the ring for a small space was fainter and apparently narrower than elsewhere. A similar appearance was observed on the same limb in 1866. The morning after the transit the sky was slightly hazy, and the planet could not be found. On the day following (the 10th) the crescent, extending to more than three-quarters of a circle, was seen with beautiful distinctness in the 9-inch equatorial, and on this and two subsequent days measurements were taken with the filar micrometer for the purpose of determining the extent of the cusps, and consequently the horizontal refraction of the atmosphere of the planet. These observations give a mean of 44′.5 as the horizontal refraction of Venus's atmosphere, or about one-quarter greater than that of the earth's. Six measurements of the diameter of the planet on the 10th give 63″.1. Twenty-four on the 11th give 63″.75."

Blondeau on the Causes of Disease.—In the *Moniteur Scientifique* for November there is a very ingenious essay, by Dr. C. Blondeau, on the causes of disease, in which the author endeavors to show that morbid states are always the result of disordered cellular function. His argument is substantially as follows: The cell exists before the organized being, virtually includes it, and survives it after the play of its organs has been arrested. Hence, in order to understand the phenomena of the organization, we must study the cell which, when its functions are not disordered, is the primary cause of life and motion, but, when they are interfered with, of death. During life, every thing depends on the cell—when the animal respires, the cell acts the chief part in that function; when a muscle contracts, it is the muscular element, the cell, that feels the action of heat and causes the muscle to move. The same is to be said of nervous and glandular action. In a word, the life of the organism is simply the resultant of the life of the cells, their individual existence being coördinated to subserve a perfectly definite object. When this coördination is interfered with, we have disease. And hence, if we would reëstablish the equilibrium, we must remove the obstacles which hinder the cell in the discharge of its functions; but to this end we must understand the nature of the agents which so interfere with its functions. These agents are all the poisons, whether organic or inorganic—whether viruses or mineral substances. The remedies to be employed, therefore, are counter-poisons, also derived from these two kingdoms. Innocuous viruses introduced into the animal economy may neutralize the dangerous effects of those which are toxic, just as certain mineral salts may destroy the disease-germ without endangering the life of the patient. Thus the germ of small-pox is neutralized by vaccine virus, and the syphilitic virus by the salts of mercury.

When it has been demonstrated that disease is the result of disordered cell-secretion, then medicine will rest upon a scientific basis. But, so long as we persist in regarding the human body as a mechanism set in motion by the same forces which act upon inorganic substances, we shall never be able, says the author, to explain the action of poisons on the organism. Until it is admitted that the blood is, for the most part, composed of organized living cells, that these cells act the principal part in forming and maintaining all our organs, and that they may undergo modifications which lead to serious maladies, we shall never be able to trace the disturbances occurring in the economy to any certain and definite cause, or to discover the proper remedies.

Tree-Planting in Towns.—The *American Garden* makes an earnest plea for the planting of trees in the streets of cities, as a sanitary measure. Growing plants assimilate the carbon of carbonic acid, discharging its oxygen into the atmosphere. The respiration of men and animals and the consumption of fuel load the atmosphere

with carbonic acid, and the only means of destroying that poisonous gas is found in plant-agency. Hence, if the atmosphere of a city were to be inclosed within impermeable walls, and there were no growing plants within the inclosure, the air would quickly become irrespirable. But of course the air is nowhere thus walled about, and hence the deleterious gases it contains are dissipated and carried away by the unceasing movement of the atmosphere to other regions where an abundant vegetation may deprive it of its carbonic acid. Still, there is no doubt that this purification of the air is accelerated by the presence of vegetation in the cities themselves. The writer in the *Garden* asserts that "Paris has now so large a number of parks, and its streets and boulevards are so profusely planted with trees, that the death-rate has been thereby reduced from one in thirty-four as it formerly was, to one in thirty-nine as it now is."

But trees are further of service in shading gutters and road-ways, thus materially retarding and preventing the action of the sun in producing noxious fermentation. Then, too, the roots of the trees take up large quantities of such matters as are washed by the rains into the interstices of the pavements. Besides these direct sanitary benefits, we must also take note of the comfort derived from the shade of the sidewalks. Last, though not least, the beauty of our cities would be greatly enhanced by the planting of trees in the streets. The author recommends the planting of the sunflower on the Harlem flats of this city. By this means the poisonous gases arising from the decaying garbage used for filling these flats would be neutralized far more effectually than by the application of either "injunctions or disinfectants."

Magnetism and the Imagination.—Dr. Volpicelli, in a communication to the French Academy of Sciences, describes certain experiments made by him to determine whether a magnet can have any influence upon persons of nervous constitution. The first person experimented on was a patient of the hospital Santo Espirito, in Rome, whom the sight of a magnet was sufficient to throw into convulsions. Volpicelli brought with him a simple piece of unmagnetized iron; this, however, produced all the effects attributed to the magnet. The second experiment was made on a person similarly affected with nervous disorder. Volpicelli placed a magnet in this person's hand, and soon the super-excitation was such that it had to be taken away. A few days later the subject of this experiment presided at a meeting of scientific men. All unknown to him, magnets had been introduced into his chair, into the drawer of his table, under his feet—in short, all around him. The meeting lasted for two hours, and, at its close, on being asked how he felt, he declared that he was perfectly well. "It appears to me," continues Dr. Volpicelli, "that these two experiments are sufficient to prove that magnetism has no effect upon the nervous system, and that the cause of the effects produced by the presence of a magnet is to be attributed only to the imagination. As I have shown, if we bring one or more powerful magnets near to a patient without his suspecting their presence, no appreciable effect is produced. For the physiologist, the most interesting circumstance connected with these experiments is the diversity of effects produced by the imagination in nervous subjects when they see a magnet, or suppose the presence of one. The diversity of these effects will, perhaps, lead to the discovery of some new truths."

A Lost Species rediscovered.—How sad the idea of the loss of a species! Suppose our robins were reduced to a single living specimen? When inevitable death should come, the going out of that one individual life would be the extinction of its race forever. There is the typical fact of the disappearance of the dodo. And at home we have the equally remarkable fact of the extinction of that noble shore-bird, the great auk. It is now fifty-five years since Major Long's expedition returned from the Rocky Mountains, bringing many unknown forms of life. Of this expedition Thomas Say was chief zoologist. Among the many new species was one especially of the *Cicindela*, or tiger-beetles, those beautiful insects which have always been favorites with the entomologists. Say described, and named it *Cicindela limbata*. At that time

the Rocky mountains were almost the *ultima Thule* of Western adventure. The same region now is wellnigh the geographical centre of the West, and has been the field of much good work by naturalists. However, that insect, although most assiduously looked for, was never found, and belief had nearly settled down that Say was in error about his new species, or that the species had become extinct. Unfortunately, Say's collections were all long ago destroyed, and only his published description of the species remained.

In the current number of *Psyche*, E. P. Austin says: "Last summer, while engaged on the survey of the north boundary of Nebraska, I visited one of the numerous hills of drifting sands with which a large part of that section is covered, when I saw a cicindela fly up, which was evidently quite different from any thing I had ever seen before; on following it, it lighted on a steep slope of bare sand, where, after some exertion, I succeeded in capturing it. By going over the sand, I saw others, and during the time that I remained in that vicinity—about an hour—they increased in frequency, a circumstance which I thought due to disturbing them in their hiding-places by trampling the sand."

On his return East, Austin worked the insect out; and lo! it was the long-lost species, *Cicindela limbata* of Say.

The rediscoverer says: "It may appear singular that the species should have remained undetected so long; but owing to its small size and great activity, as well as because it probably is confined to the barren sand-hills, which are not promising regions to collect in, it is evident that, but for its accidental discovery, it might have remained undetected much longer."

Economizing the Heat of Waste Steam.—Mr. Spence lately exhibited in London his plan for the employment of waste steam as a substitute for fuel. This method is founded on a discovery made by the father of the inventor, and announced by him to the British Association in 1869, viz., that steam liberated at atmospheric pressure, and passed into a saline solution having a boiling temperature higher than that of water, raises the solution to its own boiling-point. Thus, as Mr. Spence showed experimentally, if we take a nitrate-of-soda solution, which boils at 250°, and blow into it steam at 212°, the temperature of the solution will be raised to 250°, the steam condensing and yielding its heat. Mr. Spence uses the solution of caustic soda, both on account of its high boiling-point, and because it does not act injuriously upon iron. The exhaust steam will raise this solution to a temperature of 375°, and the heated solution is then circulated through pipes in an ordinary boiler, and its heat is radiated, for the purpose of generating steam in the place of heat derived from fresh fuel. If the boiler is at a pressure of 30 pounds, the solution will leave it at a temperature of 250°, so that 125 degrees of heat would have been yielded to the water. The solution having been to some extent diluted by the condensation of the exhaust steam, its capacity for heat will be correspondingly reduced; and, if steam at 212° were again blown through it, it would not reach the same temperature as before. It is therefore passed into another boiler of ordinary construction, where it takes the place of water, and is concentrated by steam being generated from it; and in this way its capacity for receiving heat is restored.

Mr. Spence maintained that, if, by taking advantage of his father's discovery, a mode of utilizing the large amount of latent heat contained in the steam now thrown into the atmosphere could be brought into practical operation, so that this latent heat could be made to do actual work, the discovery would be one of enormous value, and he announced his intention of speedily trying the experiment on a manufacturing scale.

Reproduction of Burnt Records.—M. Rathelot, an officer of the Paris law-courts, has succeeded, in an ingenious manner, in transcribing a number of the registers which were burnt during the Commune. These registers had remained so long in the fire that each of them seemed to have become an homogeneous block, more like a slab of charcoal than any thing else, and, when an attempt was made to detach a leaf, it fell away into powder. Many scientific men had examined these unpromising black

blocks, when M. Rathelot hit upon the following method of operation: In the first place, he cut off the back of the book so as to leave nothing but a mass of leaves, which the fire had caused to adhere to each other. He then steeped the book in water, and afterward exposed it, all wet as it was, to the heat at the mouth of a *calorifère;* the water, as it evaporated, raised the leaves, one by one, and they could be separated, but with extraordinary precautions. Each sheet was then deciphered, and the copy certified by a legal officer. In this way the records of nearly 70,000 official acts have been saved. The appearance of the pages was very curious—the writing appeared of a dull black, while the paper was of a lustrous black, something like velvet decorations on a black-satin ground, so that the entries were not difficult to read.

Sonorous Sand.—There was recently presented to the California Academy of Sciences, by W. R. Frink, of Honolulu, a specimen of "sonorous sand" from the island of Kauai, one of the Hawaiian group. In a letter accompanying the specimen, Mr. Frink states that the bank from which this sand was taken commences at a perpendicular bluff at the southwest end of the island, and extends a mile and a half almost due south, parallel with the beach, which is about 100 yards distant from the sand-bank. The latter is about sixty feet high, and is constantly extending to the south. At the extreme south end, and for half a mile north, if you slap two handfuls of the sand together, a sound is produced like the hooting of an owl. If a person kneels on the steep incline, and then, with the two hands extended and grasping as much sand as possible, slides rapidly down, carrying all the sand he can, the sound accumulates till it is like distant thunder. "But the greatest sound we produced," says Mr. Frink, "was by having one native lie upon his belly, and another take him by the feet and drag him rapidly down the incline. With this experiment the sound was terrific, and could have been heard many hundred yards away."

The sand of Jebel Nagus, a hill lying to the west of the mountain usually called Sinai, in Arabia, possesses similar properties. According to Captain H. S. Palmer, an English traveler, it gives out musical sounds whenever it is set in motion. The sound produced "is neither metallic nor vibratory. It might be compared to the sharpest notes of the Æolian harp, or to the sound caused by forcibly drawing a cork over wet glass. When at the maximum intensity it may be heard at a considerable distance."

Dr. James Blake, of the California Academy of Sciences, has investigated with the microscope the structure of the Kauai sand, and states that the grains are chiefly composed of small portions of coral, and apparently calcareous sponges. They are all more or less perforated with small holes, mostly terminating in blind cavities, which are frequently enlarged in the interior, communicating with the surface by a small opening. The structure of the grains, Dr. Blake thinks, fully explains the reason why sounds are emitted when they are set in motion. The mutual friction causes vibrations in their substance, and consequently in the sides of the cavities; and, these vibrations being communicated to the air in the cavities, the result is sound. There are, in fact, millions upon millions of resonant cavities, each giving out a sound which may well acquire a great volume, and even resemble a peal of thunder. The sand must be dry, however, in order to produce sound; for, when the cavities are filled with water, the grains are incapable of originating vibrations.

Prof. Wurtz on the Order of Nature.—Prof. Ad. Wurtz, in his address as President of the French Association, referred as follows to the ultimate questions of science: "With regard to matter, it is ever and everywhere the same, and the hydrogen of our earth's water we trace in our sun, in Sirius, and in those nebulæ which are still unformed worlds. Everywhere is motion, too; and motion, which appears inseparable from atoms which constitute matter, is the origin of all physical and chemical force. Such is the order of Nature; and the deeper Science searches into her mysteries, the more clearly it evolves the simplicity of the means used, and the infinite diversity of results. Thus, from under the edge of the

veil which we are enabled to lift, a glimpse is revealed to us of the harmonious plan of the universe. As for primary causes, they remain beyond the ken of man's mind; they lie within another domain which man's intellect will ever strive to enter and search. So is man constituted, and such he will forever continue. In vain does science reveal to him the physical structure of the universe and the order of its phenomena: he will strive onward and upward in his innate instinctive conviction that things have not within themselves their sufficient cause, their foundation and origin; he is gradually led to subordinate them to a primary cause, a unique and universal God."

Reported Discovery of Living Moas.—A report is published in an Auckland newspaper, of October 3d, of the finding of two live moas at Browning Pass, New Zealand. The story runs that one R. K. M. Smyth, on September 26th, while hunting, saw his dog set off suddenly at a great pace, barking furiously. He followed, and soon saw two large birds, one of gigantic height, the other smaller. Seeing the dog getting the worst of the fight, Smyth ran back and called his mate to assist him. They got a leather rope, and, under shelter of a small patch of bush, got behind the larger bird and roped it at the first cast. He then took a turn round a birch tree with the rope. The large bird did not show fight to any great extent, and the smaller one remained quietly by it. After this they had very little trouble to secure the legs of the large bird, and they left it fastened to the tree two days, the young one making no effort to leave its mother. With the assistance of some shepherds the old bird was taken to the camp, the young one following. The old bird is eight feet high, and the young one five feet. The story needs confirmation: it is almost too good to be true.

How Migration changes Man.—We are indebted to Rev. I. T. Beman for a copy of an address delivered by him on the "Moulding Influences of Migration upon the Human Family," particularly as exhibited in certain Yankee settlements in Southern New Jersey. The author points out the physical differences existing between these Jerseymen and New-Englanders, as follows: "The complexion of the Yankee is blond, that of the Jerseyman dark. The Jerseyman's face is more reposeful than the Yankee's, less variable in expression, and presents a heavier physiognomy. His hair is more abundant, darker, and coarser. The Yankee has smaller jaws, more slender neck, rounder chest and limbs, more arching instep, etc. As regards mental traits, the Jerseyman is slow of thought, the Yankee quick, inventive. Yet these two populations are sprung from one original stock; circumstances have made them unlike. And the same results will be produced again in the descendants of the Vineland immigrants." "Within three generations," says the author, "the essentially *Yankee* character of Vinelanders will disappear, and many peculiarities of our New-Jersey neighbors, somewhat remodeled, will be grafted upon our descendants."

Prof. Marsh on the Lake-Basins of the West.—In a memoir by Prof. O. C. Marsh, on "The Ancient Lake-Basins of the Rocky Mountain Region," published in the *American Journal of Science*, the formation of these basins is traced back to different epochs of Tertiary time on the evidence afforded by the fauna peculiar to each. The oldest of these Tertiary lake-basins are of Eocene age. The first discovered and best known of these Eocene lake-beds is the Green River basin, lying between the Rocky Mountains and the Wasatch range, in the depression now drained by the Green River. The fauna entombed in this Eocene lake indicates a tropical climate—tapiroid mammals, monkeys, crocodiles, lizards, serpents. The author cites, as an example of the Miocene basins, an ancient lake-bed lying north of the Black Hills. The fauna here discovered indicates a climate much less tropical than that of the Eocene lakes, as is seen in the absence of monkeys, and scarcity of reptilian life. At the close of the Miocene a subsidence took place east of the Rocky Mountains. A great Pliocene lake was thus formed directly over the Miocene basin just mentioned, having nearly the same boundaries on the north and west (Black Hills and Rocky Mountains), but ex-

tending much farther east, and stretching south nearly to the Gulf of Mexico. The fauna of this lake-basin indicates a warm temperate climate. The more common mammals are a mastodon, rhinoceros, camels, and horses, the latter being especially abundant.

Insect-catching Plants.—Mr. William M. Canby communicates to the *American Naturalist* some observations on the *Drosera filiformis*, or thread-leaved sundew, which confirm and supplement the observations of other naturalists on the manner in which the leaves of that plant capture insects. At 7 A. M. he placed bits of the common house-fly on sundry leaves of the drosera, near their apices; and, twelve hours later, not only had the glandular hairs around bent toward and touched the atoms of fly, but also in every case the leaves themselves had bent over them, the inflection being about 17°. There were other leaves in the vicinity which had themselves captured flies: many of these were much more bent, undoubtedly from having held the prey a longer time. In one case the leaf had curled round the prey so as completely to encircle it.

Extermination of the Thistle.—The Berlin correspondent of *Land and Water* publishes a piece of information that will be welcome to many a farmer. "Who ever knew," says he, "of two plants being so inimical to one another as one to kill the other by a mere touch? This, however, seems to be the case when rape grows near the thistle. If a field is infested by thistles, give it a turn of rapeseed, and this plant will altogether starve, suffocate, and chill the thistle out of existence. A trial was being made with different varieties of rapeseed in square plots, when it was found that the whole ground was full of thistles, and nobody believed in the rape having a fair run. But it had, and as it grew the thistle vanished, faded, turned gray, and dried up as soon as the rape-leaves began to touch it. Other trials were then made in flower-pots and garden-beds, and the thistle always had to give in, and was altogether annihilated, whether old and fully developed, or young and tender."

Food of the Bongos.—The Bongos, a negro tribe on the Upper Nile, are represented by Schweinfurth as being very indiscriminate feeders. Among them rats and field-mice are esteemed delicacies. The pursuit of these animals is a favorite occupation of the children, who tie them together by the tails in dozens, and carry on a lively barter in them among themselves. But a still greater delicacy is cat-flesh. The children place, in the narrow paths through the tall grass of that region, traps of bamboo, with living field-mice for bait. In these they catch cats. The Bongos, indeed, eat meat of all kinds, except human flesh and the flesh of dogs. They make no objection to meat that is in an advanced state of decomposition; it is then more tender, and, besides, is more nourishing, more strengthening than fresh meat. "Whenever I had cattle slaughtered," says Schweinfurth, "I saw my bearers eagerly contending for the half-digested contents of the stomach, after the manner of Esquimaux, whose only supply of vegetable food seems to come from the contents of the reindeer's paunch. They would even strip off the amphistomous worms which literally live in the stomachs of all cattle in this region, and, without more ado, put them raw into their mouths by the handful. After this, it could no longer surprise me to find that the Bongo reckons as game every thing that creeps or crawls, from rats and mice to snakes, from the carrion vulture to the mangy hyena, from the great fat earth-scorpion to the caterpillar, or the winged termite with its oily, mealworm-like body."

NOTES.

Monsieur N. Rauïs, connected with the secrétariat of the Brussels Royal Academy of the Sciences, proposes to publish a "Universal Dictionary of Academies, Learned Societies, Observatories, Universities, Museums, Libraries, Botanic Gardens," etc.—a systematic catalogue of all institutions concerned with the progress of science, letters, and the arts. He requests of the officials of such institutions everywhere to send him information about their establishments under the following heads: 1. Title; 2. Date of foundation; 3. Aims; 4. List of officials (titles only); 5. Location, with the exact address; 6. Prizes, etc., offered; 7. Property owned—such as library, archives, mu-

seum, laboratories, etc.; 8. Publications—number and class—number of volumes published since foundation—how these publications may be obtained; 9. Any other useful information. M. Rauis's address is "Académie Royale des Sciences, Place du Musée, No. 1, à Bruxelles."

THE WORLD'S PRODUCTION AND CONSUMPTION OF PAPER.—The following statistics of paper-making are given on the authority of Rudel, of Vienna, Austria: It appears that there are 3,900 paper-manufacturers in the world, employing 80,000 men and 180,000 women, besides the 100,000 employed in the rag-trade; 1,809,000,000 pounds of paper are produced annually. One-half is used in printing, a sixth for writing, and the remainder for packing and for other purposes. The United States averages 17 pounds per head; an Englishman consumes 11½ pounds; a German, 8 pounds; a Frenchman, 7 pounds; an Italian, 3½ pounds; a Spaniard, 1¼ pound; and a Russian only 1 pound annually, on an average.

ACCORDING to Worsaæ, the civilization of the Age of Bronze originated in Asia Minor, and was first adopted in Greece. From Greece and Hungary it spread over the rest of Europe. From Greece it spread into Italy, Gaul, and Britain; from Hungary, into Northern Germany and Scandinavia.

E. MONSEN, C. E., has written a pamphlet entitled "The Sewage Difficulty exploded." "The author," says *Iron*, "cuts the knot of sewage utilization, by regarding sewage as practically useless for agricultural purposes, thus restricting the question to the easiest and most economical method of rendering it innocuous. He puts his opinion in epigrammatic form when he observes that sludge and sewage require a deal of leaving alone. Having removed the insoluble matter or sludge by deposition, and brought the liquid portion into a condition sufficiently innocuous, he proposes to pass it into the rivers; the sludge he would bury or store in trenches. It will thus, he says, be put out of the way, and cease to be a nuisance."

IT is proposed to make the tidal movements in the British Channel available for compressing air to drive the engines used in excavating the Anglo-French Tunnel under the Straits of Dover.

EXPERIMENTS made by Fleck, of Dresden, on the disinfecting power of chloride of lime, caustic lime, alum, sulphate of iron, and chloralum, show that the last is by far less efficacious than the others. Alum and sulphate of iron are quite as inoffensive and innocuous as chloralum, while at the same time they are more powerful and considerably cheaper.

A NEW tonic medicine, stimulant to digestion, and having a marked action on the liver, is mentioned in the *Medical Press*. It is called *boldo*, and is obtained from the boldu, a tree which grows in Chili. One gramme of the tincture excites appetite, increases the circulation, and acts on the urine, which gives out the peculiar odor of boldo.

THE mode of fertilization of the closed gentian, the flowers of which never open, has long puzzled botanists. The corolla is twisted up so as to leave no opening at the top. The flowers are all nearly erect, with two stigmas considerably above the five anthers. An English observer has seen humble-bees entering these flowers; they pry or untwist the opening with their mouth-organs and legs, and then pop into the barrel-shaped cavity, which they just fill.

SIR CHARLES LYELL, author of "Principles of Geology," died February 23d. Deceased was born in 1797. At Oxford University he attended Buckland's lectures on geology. The first volume of his "Principles" was published in 1830. The work has reached its twelfth edition in England, and is the principal text-book of geology in that country. Lyell's "Elements" was originally a part of the "Principles." He also wrote "Geological Evidences of the Antiquity of Man." We gave a portrait of Lyell and a sketch of his life in No. II. of the Monthly.

DIED, December 31, 1874, Francis Kiernan, F. R. S., author of "Anatomical Researches on the Structure of the Liver." He was a native of Ireland, but had lived in England from boyhood. His researches earned for him his Fellowship in the Royal Society, and also the Copley Medal. He took an active part in promoting the establishment of the London University.

IT is in contemplation to send out from Germany during the present year an expedition to explore the north-polar region. The expedition is to consist of two steamships, one to explore the east coast of Greenland, the other to advance to the pole. The funds are to be raised by private subscription.

THE Highland Agricultural Society of Scotland lately resolved to memorialize the Government in behalf of agricultural education for the working-classes, that the grants of the department shall be declared to cover instruction in chemistry, mechanics, physiology, botany, morphology, and other scientific subjects, when taught in the abstract, in so far as necessary for agriculture; and also to cover instruction given in the principles of agriculture as an applied science, and to place it in the same position as machine-construction, applied mechanics,

the principles of mining, and navigation, which are already included in the list of scientific arts toward instruction in which aid is given, and in which examinations are carried out by the department.

THE use of aniline colors for tinting candies, syrups, and the like, is condemned by the *Laboratory* on account of their liability to contain arsenic. In twenty-five samples of aniline red or fuchsine, lately analyzed by Dr. Springmühl, only one was found wholly free from this poison, some of the samples containing as much as 6½ per cent. of arsenic. Cases of poisoning by these colors, as thus used, are numerous and well authenticated, and should warn consumers against brightly-colored syrups and confectionery.

ACCORDING to the *Mining and Scientific Press*, several vessels laden with coal for California were destroyed by fire last year. The cause was undoubtedly spontaneous combustion, heat being generated by the pressure and friction in the hold of the vessel. The "fire-damp" which escapes from coal-mines arises from slow decomposition of the coal at a temperature but little above that of the atmosphere.

THE Berlin Academy of Sciences has voted money for the purpose of maintaining in that city a certain number of scientific men, whose only occupation will be the investigation of science, and who will have no other duties to attend to, such as teaching, lecturing, and the like. Prof. Kirchhoff has received and accepted a "call" from the Academy.

ON the 18th of January of the present year, there died at Tring, Herts, England, a woman who had attained the extraordinary age of one hundred and eleven years and nine months. She was of pure gipsy descent, and was born in 1763 at Chinnor, Oxfordshire. Her name was Hearne, by marriage Leatherlund. The parish register of Chinnor shows that she was baptized on the 24th of April, 1763.

FROM July 25, 1775, when Benjamin Franklin was appointed Postmaster-General, until 1799, only letters and newspapers were conveyed by the United States mails. In the latter year it was provided that pamphlets and magazines also might be transported *when convenient;* and not till 1845 was mailable matter strictly defined as including letters, newspapers, and periodicals. The regulations for 1852 admitted bound books not weighing over thirty-two ounces. The act of 1861 admitted maps, engravings, seeds, and cuttings, not weighing over eight ounces, and books not over four pounds. In 1863 a number of miscellaneous articles were declared mailable, and in 1872 it was enacted that this miscellaneous matter should embrace all articles within the prescribed weight (four pounds) which were not liable to injure the mail-bag or the person of any post-office employé. Down to 1852 the post-office was self-sustaining; since that time there has always been an annual deficit, with the exception of the year 1865.

PROF. J. N. BENEDICT, who has studied the topography of the Adirondack plateau, with a view to determine the probable cost of storing up the surplus waters of that region for the use of the Hudson and other streams, reports that—1. Immense quantities of water can be safely stored at a comparatively low cost on the Upper Hudson, much of which is now worse than lost, as it runs to waste in spring freshets, which in various ways are the cause of much damage; 2. That this excess alone is sufficient to maintain a good depth of water in the main river for one hundred days in the summer. The lakes of the Racquette basin alone are stated to have a capacity more than six times that of the Black River reservoirs, which supply the eastern division of the Erie Canal.

THE "Central Ohio Scientific Association" was organized last November, at Urbana, with the following officers: President, Rev. Theodore N. Glover; Vice-President, P. R. Bennett, Jr.; Corresponding Secretary and Curator, Thomas F. Moses, M. D.,; Recording Secretary, William F. Leahy; Treasurer, J. F. Meyer. The Association holds its meetings once a month at Urbana, the county-seat of Champaign County.

THE chief of the Manchester Fire Department gives, in a late number of *Science Gossip*, several instances where leaden water-pipes were gnawed through by rats. Two cases are also cited where the rats evidently mistook a gas for a water-pipe, and gnawed through it; on both these occasions damage was done by fire, by the accidental ignition of the escaping gas. Fires have occurred through rats and mice conveying under the flooring oily and fatty rags which have afterward ignited spontaneously. This is supposed to be a common cause of fire in cotton-mills.

AT the Vienna Exposition there were exhibited specimens of paper from the bark of the mulberry, from the stinging-nettle, and from potato-stalks. The mulberry-bark used for paper is the bark stripped from twigs after the leaves have been fed to silk-worms. In Hungary the nettle is used with rags for making fine sketching and copying paper, and in Bohemia wrapping-paper is made from potato-stalks.

AT the beginning of the present year the amount contributed toward the Agassiz monument was $9,000.

INDEX.

PAGE

Address before the American Association 197, 308
Address to an Atom 639
Agriculture, Portuguese 378
Amœba, how it takes its Food 758
Anæsthetics and Metaphysics 638
Animal Movements 444
Animals not Automata 405
Anomalies, Facial 78
Antlers of Deer, Growth and Reproduction of 251
Apoplexy 705
Artificial Butter 125
" Furs 378
Atmosphere, The, in relation to Fog-Signaling. (Illustrated) 541, 685
Automaton, A Human 253

"Backing Out" 366
Bacteria and their Effects. (Illustrated) 399
Ballooning Spider 685
Bears. (Illustrated) 281
Bells, Cheap Substitute for 381
Biology for Young Beginners. (Illustrated) 340, 574
Birds'-Nests 481
Black Death in Egypt 638
Bongos, their Food 766
Brain, Experiments on 376
Books noticed:
"The Building of a Brain" (Clarke) 115
"L'Astronomie Pratique" 117
"Journal of Speculative Philosophy" 118
"One Year of Science" 120
"Exposures in Fire-Insurance" (Ross) 120
"Introduction to Biology" (MacGinley) 120
"Statistical Atlas of the United States" 120
"The Transit of Venus" (Forbes) 121
"Prof. Tyndall's Belfast Address" 121
"The Physiology of Man" (Flint) 244
"Evolution and Progress" (Gill) 245
"Animal Mechanism" (Marey) 246
"The Maintenance of Health" (Fothergill) 248
"Cave-Hunting" (Dawkins) 249
"Qualitative Analysis" (Hill) 249
"Deutsche Rundschau" 250
"Outlines of Cosmic Philosophy" (Fiske) 367
"Light-Houses" (Elliot) 370
"History of the Conflict between Religion and Science" (Draper) 371
"Chemical and Geological Essays" (Hunt) 372

the principles of mining, and navigation, which are already included in the list of scientific arts toward instruction in which aid is given, and in which examinations are carried out by the department.

THE use of aniline colors for tinting candies, syrups, and the like, is condemned by the *Laboratory* on account of their liability to contain arsenic. In twenty-five samples of aniline red or fuchsine, lately analyzed by Dr. Springmühl, only one was found wholly free from this poison, some of the samples containing as much as 6½ per cent. of arsenic. Cases of poisoning by these colors, as thus used, are numerous and well authenticated, and should warn consumers against brightly-colored syrups and confectionery.

ACCORDING to the *Mining and Scientific Press*, several vessels laden with coal for California were destroyed by fire last year. The cause was undoubtedly spontaneous combustion, heat being generated by the pressure and friction in the hold of the vessel. The "fire-damp" which escapes from coal-mines arises from slow decomposition of the coal at a temperature but little above that of the atmosphere.

THE Berlin Academy of Sciences has voted money for the purpose of maintaining in that city a certain number of scientific men, whose only occupation will be the investigation of science, and who will have no other duties to attend to, such as teaching, lecturing, and the like. Prof. Kirchhoff has received and accepted a "call" from the Academy.

ON the 18th of January of the present year, there died at Tring, Herts, England, a woman who had attained the extraordinary age of one hundred and eleven years and nine months. She was of pure gipsy descent, and was born in 1763 at Chinnor, Oxfordshire. Her name was Hearne, by marriage Leatherlund. The parish register of Chinnor shows that she was baptized on the 24th of April, 1763.

FROM July 25, 1775, when Benjamin Franklin was appointed Postmaster-General, until 1799, only letters and newspapers were conveyed by the United States mails. In the latter year it was provided that pamphlets and magazines also might be transported *when convenient;* and not till 1845 was mailable matter strictly defined as including letters, newspapers, and periodicals. The regulations for 1852 admitted bound books not weighing over thirty-two ounces. The act of 1861 admitted maps, engravings, seeds, and cuttings, not weighing over eight ounces, and books not over four pounds. In 1863 a number of miscellaneous articles were declared mailable, and in 1872 it was enacted that this miscellaneous matter should embrace all articles within the prescribed weight (four pounds) which were not liable to injure the mail-bag or the person of any post-office employé. Down to 1852 the post-office was self-sustaining; since that time there has always been an annual deficit, with the exception of the year 1865.

PROF. J. N. BENEDICT, who has studied the topography of the Adirondack plateau, with a view to determine the probable cost of storing up the surplus waters of that region for the use of the Hudson and other streams, reports that—1. Immense quantities of water can be safely stored at a comparatively low cost on the Upper Hudson, much of which is now worse than lost, as it runs to waste in spring freshets, which in various ways are the cause of much damage; 2. That this excess alone is sufficient to maintain a good depth of water in the main river for one hundred days in the summer. The lakes of the Racquette basin alone are stated to have a capacity more than six times that of the Black River reservoirs, which supply the eastern division of the Erie Canal.

THE "Central Ohio Scientific Association" was organized last November, at Urbana, with the following officers: President, Rev. Theodore N. Glover; Vice-President, P. R. Bennett, Jr.; Corresponding Secretary and Curator, Thomas F. Moses, M. D.,; Recording Secretary, William F. Leahy; Treasurer, J. F. Meyer. The Association holds its meetings once a month at Urbana, the county-seat of Champaign County.

THE chief of the Manchester Fire Department gives, in a late number of *Science Gossip*, several instances where leaden water-pipes were gnawed through by rats. Two cases are also cited where the rats evidently mistook a gas for a water-pipe, and gnawed through it; on both these occasions damage was done by fire, by the accidental ignition of the escaping gas. Fires have occurred through rats and mice conveying under the flooring oily and fatty rags which have afterward ignited spontaneously. This is supposed to be a common cause of fire in cotton-mills.

AT the Vienna Exposition there were exhibited specimens of paper from the bark of the mulberry, from the stinging-nettle, and from potato-stalks. The mulberry-bark used for paper is the bark stripped from twigs after the leaves have been fed to silk-worms. In Hungary the nettle is used with rags for making fine sketching and copying paper, and in Bohemia wrapping-paper is made from potato-stalks.

AT the beginning of the present year the amount contributed toward the Agassiz monument was $9,000.

INDEX.

PAGE

Address before the American Association 197, 308
Address to an Atom 639
Agriculture, Portuguese 378
Amœba, how it takes its Food 758
Anæsthetics and Metaphysics 638
Animal Movements 444
Animals not Automata 405
Anomalies, Facial 73
Antlers of Deer, Growth and Reproduction of 251
Apoplexy 705
Artificial Butter 125
" Furs 378
Atmosphere, The, in relation to Fog-Signaling. (Illustrated) 541, 685
Automaton, A Human 253

"Backing Out" 366
Bacteria and their Effects. (Illustrated) 399
Ballooning Spider 635
Bears. (Illustrated) 281
Bells, Cheap Substitute for 381
Biology for Young Beginners. (Illustrated) 340, 574
Birds'-Nests 481
Black Death in Egypt 638
Bongos, their Food 766
Brain, Experiments on 376
Books noticed:
" The Building of a Brain " (Clarke) 115
" L'Astronomie Pratique " 117
" Journal of Speculative Philosophy " 118
" One Year of Science " 120
" Exposures in Fire-Insurance " (Ross) 120
" Introduction to Biology " (MacGinley) 120
" Statistical Atlas of the United States " 120
" The Transit of Venus " (Forbes) 121
" Prof. Tyndall's Belfast Address " 121
" The Physiology of Man " (Flint) 244
" Evolution and Progress " (Gill) 245
" Animal Mechanism " (Marey) 246
" The Maintenance of Health " (Fothergill) 248
" Cave-Hunting " (Dawkins) 249
" Qualitative Analysis " (Hill) 249
" Deutsche Rundschau " 250
" Outlines of Cosmic Philosophy " (Fiske) 367
" Light-Houses " (Elliot) 370
" History of the Conflict between Religion and Science " (Draper) 371
" Chemical and Geological Essays " (Hunt) 372

Books noticed: PAGE
"Principles of Sociology" (Spencer) ... 372
"The Common Frog" (Mivart) ... 373
"The Native Races of the Pacific States" (Bancroft) ... 506
"Report of the Commissioner of Agriculture" ... 507
"Insanity and Disease" (Tourtellot) ... 507
"Animal Physiology" (Cleland) ... 509
"Elements of Zoology" (Harrison) ... 509
"Report of Chicago Relief Society" ... 624
"The Doctrine of Descent" (Schmidt) ... 625
"Religion as affected by Modern Materialism" (Martineau) ... 625
"Three Essays on Religion" (Mill) ... 626
"The Elements of the Psychology of Cognition" (Jardine) ... 627
"Influence of Music on Health and Mind" (Chomet) ... 628
"Tables for Determination of Minerals" (Frazer) ... 628
"Outlines of Proximate Organic Analysis" (Prescott) ... 629
"Polarization of Light" (Spottiswoode) ... 629
"Researches in Acoustics" (Mayer) ... 629
"Metallurgical Properties of Missouri Iron-Ores" (Schmidt) ... 629
"Half-Hour Recreations in Science" ... 630
"Community of Disease in Man and Other Animals" (Lindsay) ... 630
"Metamorphism in the Lignite-Beds of Dakota, etc." (Allen) ... 630
"A Ramble round the World" (Hübner) ... 630
"The Voice in Singing" (Seiler) ... 631
"Habits of Some American Birds" (Gentry) ... 631
"Nomenclature of Diseases" ... 631
"The Foes of the Farmers" ... 631
"An Elementary Treatise on Steam" (Perry) ... 631
"Minnesota Academy of Natural Sciences" ... 632
"Archives of Dermatology" ... 632
"The Protoplasm Theory" (Curtis) ... 632
"Organic Chemistry" (Watts) ... 632
"The Chemistry of Light" (Vogel) ... 750
"Scientific London" (Becker) ... 751
"Practical Treatise on Gases of Coal-Mines" (Atkinson) ... 752
"Observations of Sun-Spots" (Spoerer) ... 752
"The Elevations of Certain Datum-Points of the Great Lakes," etc. (Gardner) ... 753
"Polarization of Light" (Spottiswoode) ... 754
"What is Music?" (Rice) ... 755
"Chemical Examination of Alcoholic Liquors" (Prescott) ... 755
"Elements of Magnetism and Electricity" (Angell) ... 755
"Principles of Metal-Mining" (Collins) ... 756
"Treatment of Electricity" (Fieber) ... 756
"The Cultivation of Art" (Cooper) ... 756
"Antiquity of Christianity" (Alberger) ... 756
Brachiopoda, their Systematic Position ... 510
Butter, Artificial ... 122

Capture of Elephants ... 756
Coal in California ... 757
Catching Cold ... 636
Cause of "Cold Snaps" ... 632
Celestial Chemistry ... 420
Cell-Theory, The, in Physiology ... 634
Chameleons. (Illustrated) ... 526
Chemical Theory ... 758
Chemistry, Future of ... 276
Climate of the Glacial Period ... 374
Co-education ... 364
"Cold Snaps," Cause of ... 632
Colorado, Exploration of ... 759

PAGE
Concerning Bears. (Illustrated) 281
Confessions of a Reformed Smoker 76
Conflict, The Great 227
" of Religion and Science 361
Contagious Ophthalmia 377
Correctness of Photographs 710
Corrosion of Glass 253
Cotton-worm, Habits of the 757
Cremation among North American Indians 254
Crystalline and Molecular Forces 257
Curious Winter Climate 511

Darwin and Haeckel 592
Disease, Causes of 761
Disease, Ordinary, its Mental Aspects 562
Drought and Potato-Disease 126

Early Study of Geography 212
Earth's Rotation, Retardation of the 743
Eclipse of April, 1875 000
Educated to Death 57
Education and Invention 637
Education, Modern, A Demand of 635
" Science of 381
" Incentives in 748
Eggs, Decomposition of 375
Electrical Girl 588
Elongation of Trunks of Trees 511
Emotions, The, in Primitive Man 331
Equation, The Personal (Illustrated) 385
Evolution, Herbert Spencer and 20
" Social 604
" " its Causes 616
Evolution in Ornament. (Illustrated) 266
Evolution, Literature of 745
Experiments on Living Brain 376

Facial Anomalies 73
Fallacies, Alleged, in Science 499
First Traces of Man in Europe 672
Floating of Solid in Molten Iron 633
Flowers and Insects 636
Fog-Signaling. (Illustrated) 541, 685
Food of the Bongos 766
Fort, A Primitive 380
Fossil Horses 125
Fossil Remains of Man 379
Fraunhofer, Dr. Joseph, Sketch of. (Portrait) 739
Fuegians, how they keep warm 125
Furs, Artificial 378
Future of Chemistry 276

Genesis of Superstitions 513
Geography, Early Study of 212
Germination, Changes during 758
" Temperature of 637
Glacial Epoch and Insects 379
" Period, Climate of 374
Glass, Corrosion of 253
Great Conflict, The 227

PAGE

Growth of Deer's Antlers 251
Gunpowder, Manufacture and Conveyance of 717

Haeckel, Prof., Sketch of. (Portrait) 108
Heat as a Disinfectant 381
Hermit of Red-coats' Green. (Illustrated) 301
Horse, Paces of the. (Illustrated) 129
Horses, Fossil 125
House-heating in Sweden 254
How Leaves are blanched by Sunlight 124
How the Amœba takes its Food 758
How the Fuegians keep warm 125
Huber, Sketch of. (Portrait) 486
Human Automaton 253
Human Locomotion. (Illustrated) 48
Hydraulics of Rivers 237
Hydrophobia, Some Superstitions on 174

Illuminating Gas, New Source of 377
Incentives in Education 748
Insect-catching Plants 766
Insects and Flowers 636
Insects, Suctorial, how they feed 255
Intercollegiate Spouting-Match 622

Language, Teaching of 322, 470
Life, Matter and 110
Lightning among a Flock of Geese 378
Literature of Evolution 745
Locomotion, Human. (Illustrated) 48
Lovering's Address 197, 308

Magnetism and Imagination 762
Man in Europe, First Traces of 672
Man, how changed by Migration 765
Manufacture and Conveyance of Gunpowder 717
Marey on Animal Movements. (Illustrated) 444
Matter and Life 110
Maudsley, Dr. Henry, Sketch of. (Portrait) 612
Medicine, Siamese 378
Mental Aspects of Ordinary Disease 502
Mental Culture, Physiological Basis of 183
Mental Picturing in Science 620
Metric System of Weights and Measures 255
Milk, Voelcker on 759
Mineral-collecting 112
Moa, Fossil Remains of 379
Moas, Living 765
Mound-Builders 380

Nature, Order of 764
Natural History of the Oyster. (Illustrated) 1, 157
Nest and Eggs of Thistle-Bird 748
Nests of Birds 481
Newcomb, Prof., on American Science 238
Notes 126, 255, 382, 512, 639, 766

Observations on the Transit 509
Observatories, English 530
Odors and Life 142

PAGE
On the Correctness of Photographs 710
Ophthalmia, Contagious 377
Ornament, Evolution in. (Illustrated) 266
Ornithological Land-lubber 375
Oxidation retarded by Molecular Vibration 255
Oyster, Natural History of. (Illustrated) 1, 159

Paces of the Horse. (Illustrated) 129
Personal Equation. (Illustrated) 385
Photographs, On the Correctness of 710
Photography and the Chemical Centennial 115
Physiological Basis of Mental Culture 183
Pitcher-Plant 379
Plants growing within Eggs 634
" how they are distributed 636
" Insect-Catching 766
" Respiration of 60
Poisoned Soils 638
Portuguese Agriculture 378
Potato-Disease and Drought 126
Pottery of Mound-Builders 380
Priestley, Joseph 90

Rabbit, A Rare Species of 252
Rain-Drops on the Sea. (Illustrated) 732
Reason against Routine in teaching of Language 322
Reform, Social, Science and 504
Relations of Women to Professions 454
Reply to Critics 422
Reproduction of Burnt Records 763
Respiration of Plants 60
Retardation of the Earth's Rotation 743
Rights of Originality 114
River Hydraulics 237
Robin, Usefulness of the 124
Rotation of the Earth 250
Royal Institution and Society of Arts 655
" Society, Origin of 759

School Hygiene 633
Science and Social Reform 504
" from the Pulpit 734
Seeds, Vitality of 760
Sexes, Future Relations of the 614
Siamese Medicine 378
Smith, Dr. J. Lawrence, Sketch of. (Portrait) 233
Social Evolution 604
" " Causes of 616
Society of Arts and Royal Institution 655
Soils, Poisoned 638
Some Superstitions of Hydrophobia 174
Sonorous Sand 764
Species, A Lost, rediscovered 762
" Transmutation of 253
Spencer, Herbert, and the Doctrine of Evolution 20
Spider, The Triangle. (Illustrated) 641
"Spiritual Pirates" 599
Sponge, A Fresh-Water 758
Steam, Waste Heat of, saved 763
Struggle for Existence 376

PAGE
Superstitions, Genesis of 513
Swedish Stove 254
Systematic Position of the Brachiopoda 510

Tea-Adulteration 123
Temperature of Germination 687
Thermal Death-Point of Living Matter 185
Thistle-Bird's Nest and Eggs 743
Thistle, Extermination of 766
Tidal Influence on Vegetable and Animal Life 125
Todas, The 123
Transit of Venus. (Illustrated) 214, 509
Transmutation of Species 253
Trees in Towns 761
Triangle Spider. (Illustrated) 641
Trunks of Trees, Elongation of 511
Tyndall and his Reviewers 500
" and his Critics 422

Usefulness of the Robin 124

Venus, Recent Observations of 760
Vibration, Molecular, retarding Oxidation 255

Water-Supply of Islands. (Illustrated) 440
Weights and Measures, Metrical 255
Women and the Professions 454
Woman Suffrage 87
" " Prof. Cairnes on 112
Woman's Place in Nature 293
Worm, A, that Sparrows refuse 377
Wyman, Dr. Jeffries, Sketch of. (Portrait) 355

END OF VOLUME VI.